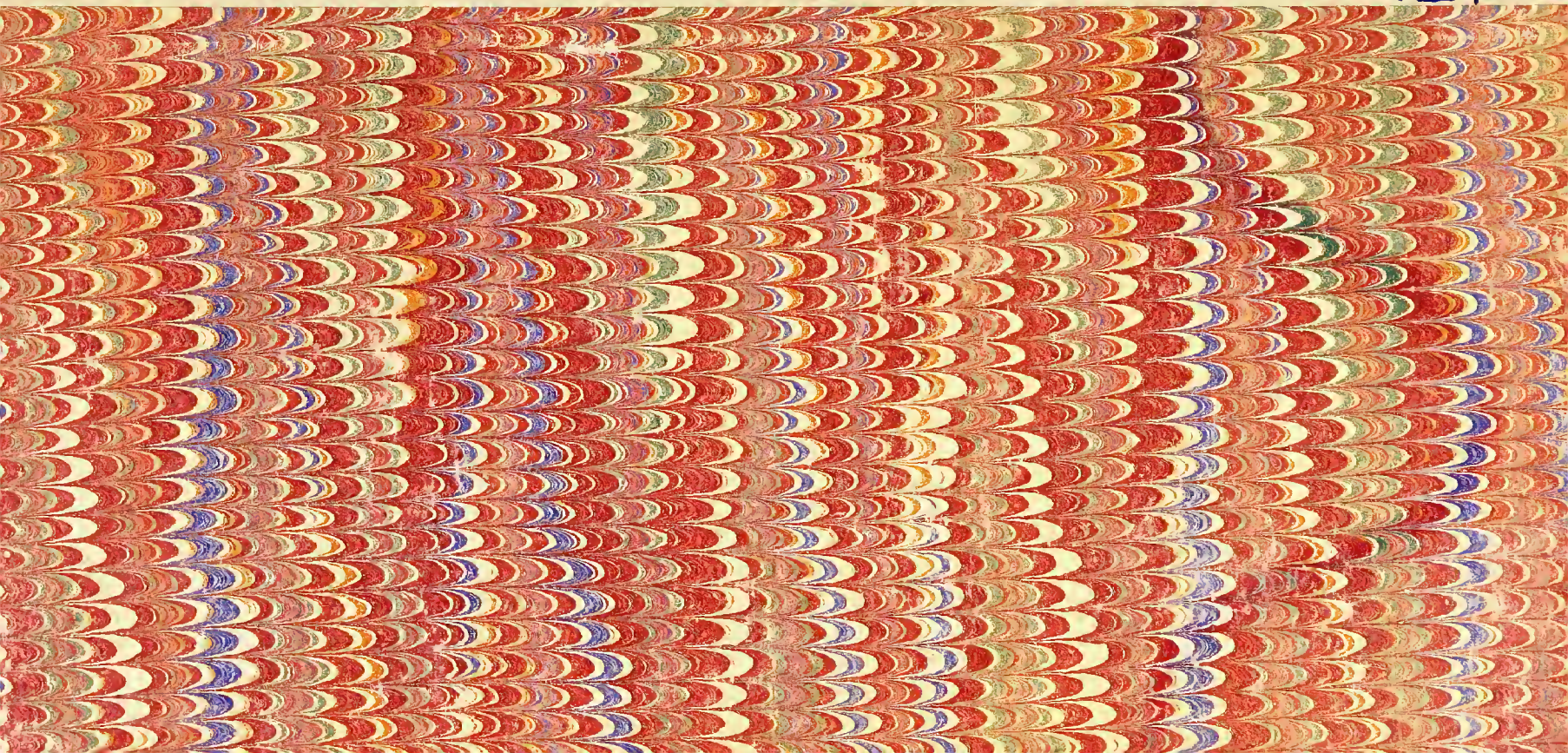

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF

PARTS OF

CAMBRIDGESHIRE AND OF SUFFOLK

(ELY, MILDENHALL, THETFORD)

(EXPLANATION OF SHEET 51 N.E. WITH PART OF 51 N.W.)

BY

W. WHITAKER, B.A., F.R.S., F.G.S., Assoc. Inst. C.E. (Editor),

H. B. WOODWARD, F.G.S., F. J. BENNETT, F.G.S.

S. B. J. SKERTCHLY, F.G.S., AND

A. J. JUKES-BROWNE, B.A., F.G.S.

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PREFACE.

The present Memoir, descriptive of Sheet 51 N.E. and the north-eastern half of Sheet 51 N.W. of the Geological Survey Map, gives an account of the Geology of parts of the counties of Cambridge and Suffolk, embracing the Isle of Ely, the towns of Thetford and Mildenhall, and the large villages of Soham, Fordham, and Isleham, besides the Icklinghams and Lakenheath (so well known in connexion with flint implements), and Wicken (noted for its phosphates and the Upware ridge).

The larger part of the area was surveyed by Mr. Skertchly, and the rest mostly by Mr. Bennett, the other officers having either mapped or revised small parts. The preparation of the Memoir has been entrusted to Mr. Whitaker. Besides editing it he has also contributed many general and some detailed notes, the chief portion of the well-sections and the supplementary bibliographies. Mr. Jukes-Browne's later work among the Cretaceous rocks has enabled him to contribute most of the account of the Gault and of the Chalk, in which he was aided by Mr. W. Hill, whose kind help the Geological Survey has already had occasion to acknowledge.

The present Memoir completes the description of the neighbourhood of Cambridge. Perhaps the most interesting geological features in it are the Corallian ridge of Upware, surveyed and described by Mr. Woodward, and the large boulder of Roslyn Hole, Ely. The implement-bearing drifts are described in Chapter VII., and the account of the Fenland is chiefly taken from the Survey Memoir on that district.

ARCH. GEIKIE,
Director-General.

31st March 1891.

U 63615. 500.—6/91. Wt. 5132.

The parts by the various authors, named on the title-page, are on the following pages :—

W. WHITAKER, 1–4, 6, 20–34, 37–39, 43, 45, 47–57, 59–64, 70–78, 80, 81, 87–90, 101 to END.

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OF PARTS

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CHAPTER I. INTRODUCTION.

Area of the District.

The area to be described consists of about 205 square miles, in Sheet 51, N.E., with about 90 in 51, N.W., or nearly 300 in all, the southern and the western parts of the latter map having already been described in a previous Memoir,* as also have the Fen beds in both maps;† but in the latter case some parts will be here repeated, so as to make this Memoir more perfect for the tract described.

With the exception of some three square miles in the north-eastern corner, including most of the town of Thetford, which is in Norfolk, the greater part of our district is in Suffolk, with the sole town of Mildenhall; but, on the west, it is in Cambridgeshire, with the city of Ely. Besides the places mentioned there are, however, many large villages.

The district is purely agricultural, the pits for chalk, clay, gravel, &c., and the getting of peat in parts of the Fens, being the only signs of mineral industry, now that the coprolite-diggings have died out.

---

* The Geology of the Neighbourhood of Cambridge. By W. H. Penning and A. J. Jukes-Browne. 1881.

† The Geology of the Fenland. By S. B. J. Skertchly. 1877.

Rivers.

The whole of the district is in the drainage-system of the *Ouse*, which river forms our boundary along its course from west of Haddenham eastward to Stretham, where it turns N.N.E. and flows by Ely into the Great Fen.

At the village of Thetford (*not* the town of the same name), south of Ely, the tributary *Cam* joins the main river, from the south. The brook from Exning (on the south), which enters the district south of Landwade, runs at first northward, but soon turns westward into Burwell Fen, the drainage of which reaches the Cam at Upware.

The stream with which we have most to do is the *Lark*, which, entering the district on the S.E. at Fornham St. Martin, flows in a general west-north-westerly course past Mildenhall, and joins the Ouse three miles N.E. of Ely, at the very margin of Sheet 51, N.W., after a course of 28 miles.

On its left, or southern, side the Lark receives the following tributaries:—(1.) Opposite Icklingham a stream from the south. (2.) Just east of Little Barton the short brook that rises in the chalk-tract at Herringswell. (3.) Between Isleham and Worlington the *Kennett*, which enters the district at Kentford and flows thence W.N.W. (4.) The brook that rises at Newmarket, just beyond our district, flows northward into Isleham Fen, through which it seems to reach the Lark.

On its right, or northern, side the Lark receives but one tributary, the westerly-flowing brook from Livermere, just beyond our eastern boundary, which itself receives a little tributary from Wordwell, close by the junction with the Lark.

The *Little Ouse* runs through the north-eastern corner of the district, from Barnham St. Gregory to below Thetford. The brook that rises south of Eriswell flows in a north-north-westerly direction into this river.

W. W.

The chalk-streams fluctuate very much in volume, and sometimes are quite dry in parts, their usual sources being, as a rule, high up in the Chalk.

The Lark was at one time navigable as far up as Bury, being canalized thus far; but the locks were not kept up, and so fell into decay; the stream, too, in many places became choked with weeds, and barges came up no higher than Mildenhall at the time of our survey. The canal, however, is now being revived, so that the navigation will again be extended upward.

F. J. B.

Geological Formations and their Range.

The district contains a somewhat varied set of formations, the eastern and larger part consisting of Cretaceous beds, whilst the western part consists chiefly of Jurassic, there being a slight

general dip in a south-easterly direction. The divisions that have been recognised are as in the following table :—

Recent	Alluvial beds	Shell-marl. Peat and Alluvium.
Post Glacial Drift	River Drift	Loam. Gravel and Sand.
		Gravel of Old Rivers.
Glacial Drift		Gravel. Boulder Clay. Loam. Gravel and Sand. Boulder Clay (local).
Cretaceous	Chalk	Upper Chalk. Middle Chalk. Lower Chalk, including the Chalk Marl.
		Gault.
		Lower Greensand.
Jurassic		Kimeridge Clay.
		Corallian Beds.

In the western part of Sheet 51, N.W. (not included here), Oxford Clay occurs.

Corallian Beds have been mapped only in the Upware peninsula, where they are represented by the Coral Rag and the Coralline Oolite (as defined by BLAKE and HUDLESTON). They probably have but a very small range underground.

The *Kimeridge Clay* is seen only in the islands in the Fen, including the large mass on which Ely stands. It probably ranges underground eastward for some way, perhaps to beyond our district.

The *Lower Greensand* is seen in outliers or in small isolated patches, on the west, being hidden, for most of its course, under the Fens. It probably extends some way underground to the east; but it is by no means certain to occur right through the district.

The *Gault* also is mostly hidden in like manner, being seen only in the Soham peninsula, except for insignificant outliers. From what we know of this formation elsewhere we may safely calculate on its persistence underground, far beyond our present bounds, to the eastern coast on the one hand and to the southern outcrop of Kent and Surrey on the other.

The *Chalk* excels all our other divisions, both in thickness and in the area taken up, being either at the surface, or next underlying the Drift, over the greater part of our district, and ranging thence northward to the sea, and in other directions (except westward and north-westward) underneath the various divisions of the Drift, of the Crag, and of the older Tertiary beds.

The various divisions of the Drift are scattered irregularly over all the above formations, those of later age following the courses

of the valleys, whilst the others occur both over the higher ground and descending into valleys.

The *Alluvial beds* form flat marshes along the streams, which run westward to the broad flat tract of the Fens.

Shape and Character of the Ground.

Our district may be said to consist of two plains. The lower one, that of the Fens, consisting chiefly of peat, and but little above the level of the sea, remarkably even, and continuous, that is to say not being cut through, but bounded only by the various masses of higher land that rise from out of it. The higher plain on the other hand, which is formed almost wholly of the Cretaceous beds and their cappings of Drift, rises slightly eastward, where the highest ground is found (though this probably nowhere reaches to 200 feet above the sea-level), and is not continuous, but cut through by the many valleys, and, on the west, by the Fen itself.

The higher plain is of much older date, has been formed by erosion, and has then been largely destroyed by eroding forces, the rivers having cut for themselves wide valleys through it; the lower plain is geologically quite modern, having been formed in the latest geologic period, by deposit, a deposit which is still going on, at its seaward end, The Wash.

Owing to the cappings of Drift, as well as to the amount of sand that seems to have been blown over the Chalk, the usual features of a chalk-tract are almost absent. We have no sharp escarpment, no deep valleys, and the flood of sand has given rise, in places, to barren heath-land, almost alike over the Boulder Clay (where that, too, is covered by the sand) and the Chalk. Over such tracts, as in the north-eastern part of the district, the only profitable crops seem to be rabbits, and sometimes firs and larch, of which large plantations have been made. That part is indeed little else than a gigantic rabbit-warren, the skins of the animals being valuable for the manufacture of felt, &c. Winged game also abounds.

With regard to the absence of a marked escarpment of the Chalk Mr. Skertchly remarks that "it is clear that such a feature once existed, but has succumbed to subaërial denudation during and since the Glacial Epoch." Mr. Jukes-Browne suggests that the dying out of the Chalk Rock (see p. 43) may have much to do with the absence of a well-marked ridge. There is, however, a fine escarpment for long distances, in more southern chalk-tracts, where Chalk Rock has not been found.

Speaking of the north-eastern corner of the district, with the bordering tract to the north (in Sheet 65), Mr. Skertchly says (in a note of about 1872): "From Thetford to the Fens so barren is the land that one is often reminded of the deserts of Africa, rather than of English scenery. Hardly a drop of surface-water

is to be found, and for miles there is neither ditch, pond, nor spring. Little cultivation is possible; but the loose sandy soil is occasionally tilled, the rental averaging about three shillings an acre. Rye is the dominant cereal, and fifty years ago was still the staple bread-stuff of the poor. Barley of good quality is grown in places, and lupins have been extensively grown of late years, for sheep-feeding. An attempt has been recently made to introduce comfrey, but this plant has hardly had a fair trial. Potatoes of good quality, and very free from disease, are grown on the poorest sands, but the crops are not heavy. Buckwheat seems to thrive."

CHAPTER II. JURASSIC BEDS.

Mr. H. B. Woodward, who mapped the Corallian Beds of Upware and made some addition to the Kimeridge Clay south of the Ouse, and who has been engaged for some years in the examination of the Jurassic formations of the South of England, has written the following description of the beds from the Oxford Clay to the Kimeridge Clay, to p. 16, some notes by Mr. Skertchly being included.

Oxford Clay.

This formation consists of greenish-grey and bluish-grey clay, with septaria, selenite, and occasional layers of sandy limestone. *Gryphæa dilatata* occurs plentifully in the upper part. The following details, supplementary to those given in the Cambridge Memoir, were noted in 1882.

The brickyard north of Willingham is abandoned, but in one part of the old pit there was to be seen stiff dark grey clay with many crystals of selenite. I picked up one specimen of *Gryphæa dilatata*, and was told by the man who dug the clay in former years, that many were then found. On showing him a specimen of *Ostrea deltoidea*, obtained elsewhere, he unhesitatingly said that the fossils he got were of the former kind.

A farmer told me that in Over Field, about half a mile north of Long Stanton Station, clay had been dug for making clay-lumps, or sun-dried bricks, used for barns and hovels.

I got no definite evidence of Oxford Clay in Willingham Field nor in Rampton Field. Between Willingham Field and The Meadows the soil is a greenish-grey clay, with gravelly patches here and there; occasionally septaria and fragments of white limestone are turned out of the ditches. Layers of white limestone occur in both Oxford and Kimeridge Clays.

Corallian Beds.

General Remarks.

The presence of rock-beds of Corallian age in certain localities in Cambridgeshire and in Huntingdonshire is a fact of remarkable interest when it is borne in mind that elsewhere over a large tract of country, from near Stanton St. John in Oxfordshire, and Quainton in Buckinghamshire, to Acklam Wold in Yorkshire, these rock-beds are unknown, and that, in their absence, it has been considered that the Oxford Clay gradually passes into the Kimeridge Clay.

The researches of Prof. H. G. Seeley have shown that a number of thin rock-beds occur in this united series of clays in Cambridgeshire and Huntingdonshire. Some of these rocks are found low down in the Oxford Clay, but others occur at or near

the border-line between the Oxford and Kimeridge Clays. Moreover a considerable thickness of clay containing an admixture of fossils belonging to these two formations, and to some extent representing the Corallian Beds, comes between them. First noticed at Bluntisham, and afterwards at Tetworth, the names of Bluntisham Clay and of Tetworth Clay were successively applied to this intervening formation; but a far better exposure being ultimately seen in the cutting of the Midland Railway at Ampthill, the name of Ampthill Clay was adopted for these passage-beds between the Oxford and the Kimeridge Clays.*

Among the rock-beds noticed by PROF. SEELEY were those at Elsworth and St. Ives, and he considered that the former rock was the newer, and occupied a position at the top of the Oxford Clay, while the St. Ives rock lay below. These views have not been confirmed, indeed palæontological evidence shows that the rocks of Elsworth and St. Ives are on the same horizon, and that they probably represent in time the Lower Calcareous Grit.

Among the fossils are *Ammonites cordatus, A. perarmatus, Pleurotomaria Münsteri, Avicula ovalis, Lima elliptica, Ostrea gregaria, Pecten fibrosus, P. lens,* &c.†

MR. T. ROBERTS has recently shown that fossiliferous clays, identical with the Ampthill Clay, can be traced through Lincolnshire, so that it appears highly probable that there is a distinct palæontological representative of the Corallian Beds in those areas of the Midland counties where no rock-beds have been found. He gives the general succession in the Cambridge area as follows:‡—

Kimeridge Clay, with a phosphatic nodule-bed at its base.
Ampthill Clay, with the Elsworth Rock, representing the Corallian.
Oxford Clay.

The question of the relation of the Upware Limestone to the Ampthill Clay is not here noticed, but there can be little doubt that the limestone comes above the clay, while the Elsworth Rock is below it.§

Ampthill Clay.

This clay is characterised by the presence of *Gryphæa dilatata* and *Ostrea deltoidea*, forms obtained at Bluntisham railway-

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* *Ann. Nat. Hist.*, ser. 3, vol. viii., pp. 503–505 (1861), and vol. x., pp. 97–110. (1862); *Geologist*, vol. iv., pp. 552, 553. (1861); *Rep. Brit. Assoc.* for 1861, *Sections*, pp. 132, 133. (1862); and Index to Fossil Remains of Aves, &c. 1869, p. 109.

† BLAKE and HUDLESTON, *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 313. (1877.)

‡ Sedgwick Essay for 1885 (not published), quoted in *Quart. Journ. Geol. Soc.*, vol. xlv., p. 547. (1889.)

§ See also PROF. MORRIS, *Proc. Geol. Assoc.*, vol. ii., no. 5, p. 220 (1872), and PROF. T. MCK. HUGHES, *ibid.*, vol. viii., no. 7, p. 461. (1884.)

cutting by PROF. SEELEY. A full list of the fossils has been given by MR. T. ROBERTS.* The beds representing the Ampthill Clay in this district are coloured with the Oxford Clay on the map.

PROF. SEELEY says of the railway-cutting S.W. of Bluntisham, that "just below the surface, is found a rock, of a grey-blue colour and unknown thickness, which was so hard that it had to be blasted in laying the railway drain. I have a fragment, containing iron-shot oolitic grains and shells, quite resembling the rock of Elsworth," and from this clay he records *Ammonites alternans*, *A. biplex*, *A. serratus* [= *A. cordatus*, var. *excavatus*], *Belemnites excentricus*, *Gryphæa dilatata* (abundant), and *Ostrea deltoidea* (rare).

He also mentions that at Over "*Belemnites excentricus* and some other fossils have been met with, identical with those of Bluntisham," while Mr. James Carter had a series of fossils "which he believes came from Holiwell," and these indicate the horizon of the Elsworth Rock.†

Coral Rag and Coralline Oolite.

Perhaps the earliest mention of the rock at Upware is by C. VANCOUVER in 1794, who says that "The arable land [of this part of the parish of 'Wickin'] consists of a deep brown mould, upon a dry bed of ragstone."‡

The earliest description of the beds, appears to be by FITTON, in his classic paper on the Strata between the Chalk and the Oxford Oolite, which was read in 1827.§ His attention was evidently drawn to the subject by SEDGWICK,‖ who, in conjunction with MR. MCLAUCHLAN, had formed a collection of fossils from the stone-beds of the Upware quarries.

According to Fitton the "Oxford Oolite" occurs "in a low ridge extending for about three miles north of Upware . . . The stone beds have been opened here in two or three quarries . . . The strata are slightly inclined to the west of north, in a direction opposite to that of the beds below the chalk. The stone here laid bare to a depth of about 10 or 12 feet, consists of a loose rubbly limestone, of a cream colour, in some places coarsely oolitic."

He adds, "The coralline beds (the proper "Coral Rag" of Smith) do not come up to the surface at this place; but they break out, Mr. Sedgwick informs me, beyond Haddenham, going towards Chatteris;" but this is a mistake, and Sedgwick makes no reference to it, when alluding to the Upware rock, in 1860; indeed he states that "for many miles in the general range of the series, both towards the N.E. and the S.W., no traces of this Coraline deposit have been met with."¶

The Corallian beds of Upware are now exposed in two quarries, and were formerly opened up in a third quarry east of High Fen Farm.

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* *Quart. Journ. Geol. Soc.*, vol. xlv., p. 556. (1889.)

† *Ann. Nat. Hist.*, ser. 3, vol. x., pp. 101, 107, 110. (1862.)

‡ General View of the Agriculture in the County of Cambridge. p. 134. *London.*

§ *Trans. Geol. Soc.*, ser. 2, vol. iv., pp. 307, 317, pl. xa. (1836.)

‖ SEDGWICK alludes to the Cambridgeshire "Coral Rag Oolite" in 1832, in the second edition of his Syllabus.

¶ A Lecture on the Strata near Cambridge . . , p. 22. Privately printed. 1861.

When mapping this tract in 1880 I noticed traces of the Coralline Oolite to the south of Padney, where it is overlain in places by a thin covering of Drift sand and gravel (with flints, &c.). The stone, locally known as "marlstone," comes near the surface a little to the south-west of Padney Farm, and there are indications of what a labourer said he believed to have been an old stone-pit.

Mr. S. B. J. Skertchly, whose notes were made in 1873, says that "the well at the cottage by the old pit (marked at the junction of the roads east of High Fen Farm) is bricked for about 10 feet down, beneath which a white calcareous-looking rock is seen. The quarry is filled up, and corn now grows upon its site." In the site of this old quarry I picked up (in 1889) small specimens of oolite of the same character as the rock in the quarry now described.

The quarry south-west of High Fen Farm, usually known as the northern pit, is now abandoned and partially filled with water. The following description of the beds was written by Mr. Skertchly in 1873:—

"The section on the eastern side of the pit is as follows":—

Soil, full of large oolitic grains about the size of rape-seed and lentils; 9 inches to a foot.

Friable cream-coloured calcareous bed, composed of large oolitic grains in a marly matrix, with iron-shot markings; and with calcareous nodules, composed of the grains cemented, from the size of a walnut to 3 or 4 inches; 2 feet 8 inches.

Bed like that above, but more clayey, and mottled with iron-stains; 6 inches.

Three courses, about a foot thick, of stone, rather deeper in colour than the upper beds; 3 feet.

Continuation of the stone beds (?) seen in the sides of the cut to a depth of 3 feet.

"The stone is very soft, scarcely worthy of the name of stone, large pieces 6 inches thick being easily broken by the hand. It is composed of large oolitic grains and minute shells, encrusted with calcareous matter. The texture is rather open. A few obscure bivalve-shells occur throughout the whole deposit. The beds dip S.S.E. at about 3°. The stone is divided by irregular joint-planes about perpendicular to the bedding, and comes away in irregular lumps from 2 to 6 inches in thickness, and from 1 to 3 feet square."

"The northern side of the quarry is very much overgrown, but presented an interesting feature. This was a big patch of Kimeridge Clay, which I drew carefully, commented on largely in my note-book, and found afterwards to have been brought from Roslyn Hole, Ely, to stop a strong spring that burst out there!"

When I revisited this quarry in 1889 it showed only 8 or 9 feet of crumbly oolitic and pisolitic limestone, reminding me of the Osmington oolite of Weymouth. Prof. Bonney remarks that the heart of the rock is often greyish blue, and he first pointed out the general distinction between the beds in this and in the southern quarry.* Messrs. Blake and Hudleston note that at their visit about 12 feet of the Coralline Oolite was exposed, dipping to the south. They mention that *Echinobrissus scutatus* and *Holectypus depressus* are numerous, while other fossils include *Littorina muricata* (var.), *Gervillia aviculoides*, *Opis Phillipsii*, &c.†

Further south the oolite was shown (in 1880) in several places by the side of the lane leading towards the southern quarry, and by the side of the lane leading from Wicken Lamas Ground towards Fen Side.

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* Cambridgeshire Geology, p. 17. (1875.)

† *Quart. Journ. Geol. Soc.*, vol. xxxiii., pp. 314, 315. (1877.)

In the field to the south of this lane I picked up, in 1889, pieces of oolite and also some corals, suggesting that thereabouts the rock shown in the southern quarry (Coral Rag) overlies that of the northern (Coralline Oolite).

Mr. Skertchly also notes that "Along the road leading towards Upware from the northern quarry the Coral Rag is seen on the side, at a somewhat higher level than any bed in the pit (perhaps by 8 feet), and the stone is rubbly, fine-grained and hard, weathering like Cornbrash. The oolitic grains are small, and casts of coral are sparingly found."

The southern quarry is about half a mile north of the inn Five Miles from Anywhere. Here, as Messrs. Blake and Hudleston observe, "the beds dip N. by W., at an angle of about 4°, so as to expose on the whole about 20 feet. Generally described, it is entirely a creamy white but rather irregular limestone, in parts crystalline. It contains, however, several layers of considerable size, composed of *Thamnastræa arachnoides*, *Rhabdophyllia*, &c. Between the more crystalline portions are some more earthy parts, containing abundance of shells, some complete, but others almost rolled into oolitic granules. The fossils in some beds have entirely perished, leaving, however, external casts, with loose internal casts inside. The corals and other fossils . . prove this to be the true Coral Rag as we have restricted the term." *

In addition to the Corals, spines of *Cidaris florigemma*, *Pecten vimineus*, *Lithodomus inclusus*, *Millericrinus*, &c. have been found.

When I saw the quarry in 1889, accompanied by my colleague Mr. A. C. G. Cameron, the section was not very clear, but the rock (a pale cream-coloured oolite, bluish-grey where unweathered) is occasionally worked for road-mending. The Coral-beds with *Cidaris*, &c. occur in the upper 8 or 10 feet, while the lower beds consist largely of rolled shell-fragments. At the base we observed shelly and oolitic marly limestone, resembling the beds in the northern quarry: thus confirming the view of Messrs. Blake and Hudleston that the beds here overlie those seen in the northern pit. Mr. T. Roberts subsequently informed me that he had come to the same conclusion. The section given by Messrs. Blake and Hudleston † (confessedly diagrammatic) shows the Corallian beds with synclinal structure, overlain by Neocomian beds. These latter are shown to extend along the Upware ridge, whereas the Corallian rocks occur there at the surface, the newer beds only appearing as a fringe on the western side of the ridge for a short distance between the two quarries.

With regard to the dip of the beds there is much diversity of opinion. On the one hand, Fitton (referring evidently to the southern pit) remarked that the strata are slightly inclined to the west of north, and this view is supported by Messrs. Blake and Hudleston, who estimate the angle at about 4°.‡ On the other hand, Mr. Skertchly says, "The Coral Rag appears to dip towards the fens S. or W., but it is obscure. The angle is from 2° to 4°. There is perhaps an anticlinal, since the beds in the other pit dipped about 3° in a south-easterly direction." In the northern pit the dip is stated by Messrs. Blake and Hudleston to be south; whereas Prof. Bonney remarks that, so far as there is any, it is northward, probably a little west of north.§

Considering the irregularity of the bedding, my own impression is that no trustworthy dip is seen; but, judging by the thickness of the beds, it seems most probable that one or more gentle undulations affect them.

Fitton indeed represented the beds as occurring in an anticlinal,‖ and Prof. Bonney has expressed himself in favour of this view.¶ It may also be noted that Prof. Seeley considered there was evidence of an anticlinal in

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* *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 314.
† *Quart. Journ. Geol. Soc.*, vol. xxxiii., fig. 9, p. 315.
‡ See also *Geol. Mag.*, dec. ii., vol. v., p. 90. (1878.)
§ *Geol. Mag.*, dec. ii., vol. iv., p. 476. (1877.)
‖ *Trans. Geol. Soc.*, ser. 2, vol. iv., pl. xa, fig. 24.
¶ *Geol. Mag.*, dec. ii., vol. iv., p. 476. (1877.)

the Oxford Clay near St. Ives ;* and this view is supported by MESSRS. PENNING and JUKES-BROWNE.† PROF. SEELEY also spoke of a possible synclinal between St. Ives and Over.

PROF. SEELEY, using the name "Upware Limestone," regarded the rock as underlain by the Ampthill Clay ; but we have ne evidence of this. He also regarded the Upware rock as a reef.‡

MESSRS. BLAKE and HUDLESTON ,in speaking of the Coral Rag of the southern pit, state that " The irregularity of the bedding is an indication of its reef-like character, to which, and not entirely to denudation, its termination may be due."§ PROF. BONNEY, too, had regarded the Upware rock as " a reef in the generally incoralliferous interval " between the beds in Yorkshire and Oxfordshire.‖

The evidence (obtained by MR. T. ROBERTS) of the coprolitic band at the base of the Kimeridge Clay is suggestive of some pause, if not of denudation ; but more facts, from borings, &c., are wanted, before it can be decided whether the Upware rock is purely a local accumulation, or whether it has suffered denudation, in Upper Oolitic times, and thus is overlapped westward by the Kimeridge Clay.

In 1868 MR. H. KEEPING published a section of the strata at Upware (reproduced on p. 23) showing Neocomian beds, &c. resting on Kimeridge Clay and on Corallian rocks. The Kimeridge Clay he believed to be unconformable to the Corallian Beds, and he noted a bed of " Coral Rag intermixed with Kimmeridge Clay " as intervening.¶ Subsequently his son, MR. W. KEEPING, published another section across the district, and expressed his opinion that the Kimeridge Clay was not unconformable to the underlying rock. He remarked that " for some depth around the present outcrop of the Coral Rag this latter rock has been bared of its covering of Kimmeridge Clay so that the phosphatic bed of the Lower Greensand comes to overlap on to the coral rag. The destructive work of the removal of the Kimmeridge Clay went on during the earlier times of the formation of the Lower Greensand, and one of its results was the production of a curious deposit composed of irregular broken fragments of coral rag mixed up with the clayey material of the Kimmeridge Clay in such a manner that it actually presents the appearance of Boulder Drift."**

MR. SKERTCHLY, in his notes, says " It seems to be as probable that the Cretaceous beds were deposited against the Coral Rag as that they were faulted against it, the form of the ground admitting of both interpretations."

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* *Ann. Nat. Hist.*, ser. 3, vol. x., p. 110.

† Geology of Cambridge, p. 6.

‡ *Ann. Nat. Hist.*, ser. 3., vol. viii. p. 504. (1861) ; and Index to the Fossil Remains of Aves, &c. 1869.

§ *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 314.

‖ Cambridgeshire Geology, p. 19.

¶ *Geol. Mag.*, vol. v., p. 273. *See* also BONNEY, Cambridgeshire Geology, pp. 63–68.

** Fossils of Upware, &c., 1873, pp. 3, 5.

Fossils of the Coral Rag.

The following revised list of Corallian fossils from Upware, drawn up for the Sedgwick Essay of 1885 (not yet published) has been kindly communicated by MR. T. ROBERTS, of the Woodwardian Museum, Cambridge.

Lists have been published by PROF. BONNEY (Cambridgeshire Geology, pp. 18, 19) and by MESSRS. BLAKE and HUDLESTON (*Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 314, and *Geol. Mag.*, dec. ii., vol. v., p. 92).

N. = from the Northern Pit. S. = from the Southern Pit.

Cephalopoda.

Ammonites Achilles, *D'Orb.*	— S.	Ammonites vertebralis, var. cawtonensis, *Bl.* and *Hudl.*	— S.
—— mutabilis, *Sow.*	— S.		
—— perarmatus, *Sow.*	N. —	Belemnites abbreviatus, *Mill.*	N. —
—— plicatilis, *Sow.*	N. S.		

Gasteropoda.

Alaria	— S.	Neritopsis Guerrei, *Heb.* and *Desl.*	— S.
Cerithium muricatum, *Sow.*	— S.	Pleurotomaria reticulata, *Sow.*	— S.
Chemnitzia heddingtonensis, *Sow.*	— S.	—— sp. (cast)	N. S.
Emarginula Goldfussi, *Roem.*	— S.	Pseudomelania striata, *Sow.*	— S.
Fissurella corallensis, *Buv.*	— S.	Trochotoma tornata, *Phil.*	— S.
Littorina Meriani, *Goldf.*	— S.	Trochus	— S.
—— muricata, *Sow.*	N. S.	Turbo princeps, *Roem.*	— S.
Natica clymenia, *D'Orb.*	— S.	—— sp.	— S.
—— clytia, *D'Orb.*	— S.		
Neritopsis decussata, *Münst.*	— S.		

Lamellibranchiata.

Anomia suprajurensis, *Buv.*	— S.	Lucina moreana, *Buv.*	— S.
Arca æmula, *Phil.*	— S.	Modiola bipartita, *Sow.*	N. —
—— contracta, *Phil.*	— S.	—— cf. rauraciensis, *Greppin.*	— S.
—— pectinata, *Phil.*	— S.	—— subæquiplicata, *Roem.*	— S.
—— quadrisulcata, *Sow.*	— S.	—— sp.	— S.
Astarte aytonensis, *Mor.* and *Lyc.*	— S.	—— (Lithodomus) iuclusus, *Phil.*	— S.
—— ovata, *Smith*	— S.	Myacites decurtata, *Goldf.*	— S.
—— sp.	— S.	—— recurva, *Phil.*	— S.
Cardita ovalis, *Quenst.*	— S.	Myoconcha texta, *Buv.*	— S.
Cardium, cf. delibatum, *De Lor.*	— S.	Mytilus ungulatus, *Young* and *Bird*	N. S.
Cucullæa elongata, *Phil.*	— S.	Opis corallina, *Damon*	— S.
Cypricardia glabra, *Bl.* and *Hudl.*	— S.	—— lunulata, *Roem.*	— S.
Exogyra nana, *Sow.*	— S.	—— Phillipsii, *Mor.*	N. S.
Gastrochæna moreana, *Buv.*	— S.	—— virdunensis, *Buv.*	— S.
Gervillia angustata, *Roem.*	— S.	—— near to paradoxica, *Buv.*	— S.
—— aviculoides, *Sow.*	N. S.?	Ostrea gregaria, *Sow.*	— S.
Goniomya v-scripta, *Sow.*	— S.	—— solitaria, *Sow.*	— S.
Hinnites velatus, *Goldf.*	— S.	Pecten articulatus, *Sch.*	— S.
—— sp., cf. corallina, *Hudl.*	— S.	—— fibrosus, *Sow.*	N. S.?
Homomya tremula, *Buv.*	— S.	—— vimineus, *Sow.*	— S.
Isoarca multistriata, *Et.*	— S.	Perna subplana, *Et.*	— S.
—— texta, *Quenst.*	— S.	Pholadomya decemcostata, *Roem.*	— S.
Lima elliptica, *Whit.*	— S.	Plicatula fistulosa, *Mor.* and *Lyc.*	— S.
—— rigida, *Sow.*	— S.	Quenstedtia lævigata, *Phil.*	— S.
—— rudis, *Sow.*	— S.	———— var. gibbosa, *Hudl.*	— S.
—— sp.	— S.	Trigonia Meriani, *Ag.*	— S.
Lucina globosa, *Buv.*	— S.		

Brachiopoda.

Rhynchonella, small -	— S.	Terebratula, small -	— S.
Terebratula insignis, var. maltonensis, *Oppel.* -	— S.		

Crustacea.

Gastrosacus Wetzleri, *Meyer*	— S.	Prosopon rostratum, *Meyer*	— S.
Glyphea - - -	— S.	—— sp. - - -	— S.

Annelida.

Serpula - - -	— S.	Vermicularia - -	— S.

Echinodermata.

Apiocrinus polycyphus, *Des.*	— S.	Holectypus depressus, *Leske*	
Cidaris florigemma, *Phil.* -	— S.	(very common in the	
—— Smithii, *Wright* -	— S.	upper part of the	
Collyrites bicordata, *Leske.*	N. S.	northern pit) -	N. S.
Echinobrissus scutatus, *Lam.*		Hybodus gibberulus, *Ag.*	N. —
(very common in the		—— n. sp. - - -	— S.
upper part of the		Millericrinus - -	— S.
northern pit) -	N. S.	Pseudodiadema versipora,	
Hemicidaris intermedia,		*Phil.* - -	N. —
Flem. - - -	— S.	Pygaster umbrella, *Ag.* -	N. S.
		Stomechinus gyratus, *Ag.* -	— S.

Actinozoa.

Isastræa explanata, *Goldf.* -	— S.	Stylina tubulifera, *Phil.* -	— S.
Montlivaltia dispar, *Phil.* -	— S.	Thamnastræa arachnoides,	
Rhabdophyllia Phillipsii,		*Park.* -	— S.
Edw. - -	— S.	—— concinna, *Goldf.* -	— S.

Spongida. Scyphia, — S.

Kimeridge Clay.

General Remarks.

The Kimeridge Clay of Cambridgeshire consists of dark grey or blackish clays and paper-shales, with occasional septaria and, in places, many crystals of selenite. Palæontologically the formation has been divided as follows :—

Upper Division.	Clays and Shales	with *Discina latissima.* ,, *Exogyra virgula.*
Lower Division.	Clays - -	,, *Ammonites alternans.* ,, *Astarte supracorallina.* ,, *Ostrea deltoidea.*

The lowest four divisions are grouped as Lower Kimeridge by Mr. T. Roberts, who has determined the succession of these zones.* He remarks that a layer of phosphatic nodules occur at the base of the formation, and the clays immediately above are crowded with *Ostrea deltoidea*, a fossil that prevails at this horizon in other localities in this country. The beds with

* *Quart. Journ. Geol. Soc.*, vol. xlv., pp. 557, 558. (1889.)

Exogyra virgula are, however, usually grouped with the Upper Kimeridge Clay, and as there is no marked plane of division in the formation, we see no reason to depart from the ordinary classification.

Concerning the full thickness of the Kimeridge Clay in the area we have no trustworthy data. A well-section at Stretham Fen has been thought to pass through 110 feet of this formation;* but it is by no means certain that the clay is Kimeridge Clay; indeed, judging by the map, it is as likely to be Gault. More evidence is needed of the nature of the clay around Fordey Farm, to the north of the Upware ridge, but I obtained no evidence to modify MR. SKERTCHLY'S original mapping of that tract as Gault.

PROF. BONNEY says that at Ely the thickness of the Kimeridge Clay is said to be about 60 feet;† and the REV. O. FISHER has stated that a well commenced in this clay at Ely "soon reached the Oxford Clay with a thin stony band containing *Nerinæa* intervening."‡ It should be mentioned that we have no record of *Nerinæa* from the Upware limestone, nor from the Elsworth rock, though *Chemnitzia* and other Gasteropods have been obtained.

Again, the estimate of 135 feet for Kimeridge Clay at Lolworth,§ six miles N.W. of Cambridge (Sheet 51, S.W.), cannot be regarded as conclusive, for it is mentioned that a bed of rock occurred 30 feet from the surface, and this rock may be on the horizon of that at Boxworth, or near the junction of the Oxford and Kimeridge Clays.

Local Details.

In 1882 attention was called by PROF. HUGHES to the occurrence of Kimeridge Clay fossils at Balsar's Hill, east of Willingham, in a tract previously regarded as Oxford Clay. Early in the spring of that year I examined the area, for the purpose of mapping the Kimeridge Clay, and made the following notes, but did not attempt to distinguish the Corallian clays (Ampthill Clay) which the researches of PROF. SEELEY, and more recently of MR. T. ROBERTS, have shown to occur in this district.

The first indication of this clay I obtained in a specimen of *Ostrea deltoidea* from a drain freshly opened just south-east of the barn (not on the map), about half-way between Cow Common and Balsar's Hill. Finding that this Oyster is mentioned from the Oxford Clay,‖ I began to think that the evidence was worth little: but PROF. HUGHES subsequently informed me that the specimen obtained by PROF. SEELEY from the "Oxford Clay" of Boxworth (now regarded as Corallian by MR. ROBERTS) was a *variety* of *O. deltoidea*.

A dyke running in a northerly direction, not quite half a mile west of Balsar's Hill, showed dark blue and grey shaly clay, with here and there

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* Geology of Cambridge (*Geol. Survey Memoir*), p. 165.
† Cambridgeshire Geology, p. 20.
‡ *Geol. Mag.*, vol. v., p. 410. (1868.)
§ Geology of Cambridge, p. 162.
‖ Geology of Cambridge, p. 7.

streaks of ochreous matter: small crystals of selenite were abundant, and there were occasional septaria. From the clay (in place) I got several large specimens of *Ostrea deltoidea*; and a number of other fossils and "coprolites" were found in heaps of clay thrown out of the ditch. Here and there very thin traces of gravelly or sandy soil occurred; but there could be no doubt from the character of the fossils and from their state of preservation that they came out of the clay. Small black "coprolites" were numerous: they are noted on Mr. Penning's working map in several places. My belief is that they belong to the Kimeridge Clay, and Mr. T. Roberts informs me (1889) that he regards the coprolitic band as the base of the Kimeridge Clay. I took them directly out of the clay in the banks of the dyke, and fossils are found attached to them. On a second visit, with Prof. Hughes, he obtained (and carried off) a specimen to which was attached a specimen of *Exogyra nana*, a shell somewhat abundant at this locality. The fossils found here are entered in the list on pp. 18, 19.

At Balsar's Hill there is an old camp. A ditch was excavated in bluish-grey clay with a band of hard and compact limestone; the beds yielded fragments of *Ostrea*, and one perfect specimen of *Ostrea deltoidea*, which Prof. Hughes unearthed. The spot where he first noticed Kimeridge Clay fossils was in a ditch running at right angles to the ditch (previously mentioned) in which I obtained most of my fossils.

About a quarter of a mile to the north, and S.S.E. of Balsar's Hill, a ditch (in course of construction) showed a layer of pale grey and cream-coloured limestone, in some places hard, in others soft and earthy.

In a shallow pit, nearly full of water, to the south of Cow Common, beneath a sandy and gravelly soil, there was a calcareous deposit, that looked much like *débris* of Coral Rag. Beneath this, clay had been dug for the manufacture of clay-lumps. Calcareous matter, however, is common in the gravels of this district.*

There is a tolerably well-marked feature, which was adopted for the boundary-line of the Kimeridge Clay between Willingham and Balsar's Hill. There appears to be no reason for a feature, but as the Oxford Clay occurs at the old brickyard north of Willingham, and the Kimeridge Clay occurs on the rising ground to the east, the safest place to draw the line is at this feature.

How far to the south the Kimeridge Clay may extend I am at a loss to say, there was no evidence of one thing or another east of Willingham Field and north of Rampton Field.† A trial-boring at Rampton (probably near the church), is recorded as in Oxford Clay.

If the coprolites truly belong to the Kimeridge Clay, and if the spots marked as yielding coprolites, on Mr. Penning's working-maps, indicate coprolites in place, then the line for Kimeridge Clay ought to be drawn much further south. On the other hand, the coprolites may in many places be surface-specimens, the relics of an eroded Kimeridge deposit, or coprolites of newer ages.

I picked up one specimen of *Exogyra virgula*, but it was in soil turned out of the pit south of Cow Common.

The large pit at Roslyn Hole, Ely, affords the best section of the Kimeridge Clay in the district. Here the clay has for a long period been dug for mending or tamping the banks of the Fen-dykes.

Many remains of Saurians and of Fishes have been got from this pit by Mr. Marshall Fisher, of Ely (see Notes by Mr. E. T. Newton, pp. 16–18).

Among other fossils recorded are *Rhynchonella inconstans* and *Ostrea deltoidea*, suggestive of the lower beds of the Kimeridge Clay, and *Ammonites biplex*, *Cardium striatulum*, *Discina latissima*, &c. suggestive of the higher beds.

Prof. J. F. Blake says: "At Ely very little is seen of the Upper Kimmeridge; for although not more than 32 feet of strata are exposed, the upper portion is papery and bituminous, and contains *Lucina minus-*

* Geology of Cambridge, pp. 90, &c.

† Geology of Cambridge, p. 168.

cula, Discina latissima, Cardium striatulum, with other fossils; while below the more clayey beds contain *Amm. serratus* and other species characteristic of Lower Kimmeridge, *Exogyra virgula* forming a whole band intermediate between them and going up into the shales."*

Mr. Skertchly took the following measurements of the Kimeridge Clay in the south-eastern corner of the great pit in 1874:—

	Feet.
Clayey soil	2
Light-blue clay, with ferruginous stains and patches of a white friable material	2
Ochreous band, mixed with tough blackish clay; 2 inches.	
Laminated, light-blue, rather tough clay, with brown mottling, and with much of the white material (as above), *Exogyra virgula*, and other shells	2
Dark blue, finely laminated, soft clay, breaking into very small fragments, full of fossils	3½
Lighter-coloured, more compact clay, divided by joint-planes into trapeziform fragments	2¼
Layer of septaria, very large, elliptical, with a tendency to form a bed (one mass measured 3½ × 3 × 1½ feet)	1½
Clay, like the above, but not so compact	1¼
Ochreous layer, with *Exogyra virgula*, 2 inches	½
†Light-blue clay, like the above ,,	
†Dark blue clay, full of shells ,,	
Lighter-blue clay; *Exogyra virgula* very plentiful	2
Ochreous layer, an inch.	
Clay, like the above	1
Layer of septaria, like the one above	1½
Section hidden at the bottom for	10

Lower beds, however, were seen to the west, but were not measured.

Mr. Skertchly also noted that "at the southern end of Thorney Hill there was a good pit-section, in 1874."

Fossils.

Notes on Mr. Marshall Fisher's Collection of Vertebrate Fossils, at Ely, obtained from the Kimeridge Clay of the neighbourhood, and chiefly from Roswell Pit. By E. T. Newton, F.G.S.

This collection comprises a large number of vertebræ and limb-bones of *Ichthyosaurus, Plesiosaurus,* and *Pliosaurus;* besides other Reptilian and Fish remains. An endeavour has been made to determine the species to which some of the *Enaliosauria* belong, and more especially to correlate them with the species given by Prof. J. Phillips.‡ Much information as to the characters of the pectoral and pelvic arches are given by Mr. J. W. Hulke in his address to the Geological Society;§ but one is forcibly reminded of the difficulty, not to say the impossibility, of determining the species to which separate parts belong.

* *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 201. (1875.)

† There is a little doubt whether the thicknesses of these may not be meant for feet instead of inches.

‡ Geology of Oxford. 8vo. *Oxford*, 1871.

§ *Quart. Journ. Geol. Soc.*, vol. xxxix., *Proc.*, pp. 44-64. (1883.)

Many of the vertebræ have been obtained in series, and evidently represent a number of different species. The limb-bones are of various sizes, and some of them agree in form with those of described species. The largest of the limb-bones is 38 inches long and 15 wide at the distal end; probably it was two inches wider when perfect.

Some large pectoral and pelvic bones are likely to be of assistance in elucidating the structure of these parts. One example includes what appear to be the two coracoids and two precoracoids, as well as parts of the scapulæ and a limb-bone. This specimen agrees very closely with Mr. Hulke's figure of the shoulder-girdle of *Pliosaurus* but has the hinder ends of the coracoids more expanded laterally, the two together having a width of 25 inches, the length of the specimen being 28 inches. The greater part of the coracoids and of the pre-coracoids are preserved, but the processes of the scapulæ are broken off. The limb-bone preserved with this specimen somewhat resembles Phillips' figure clix.

There are many teeth of *Pliosaurus*, some as large as those of *P. macromerus*, Phil (=*P. grandis*, Owen), others much smaller, which probably belong to a second species, and may be *P. brachydeirus*.

The genus *Steneosaurus* is apparently represented by two or three scapulæ, two femora, and some teeth. The femora are of two very different sizes, and probably belong to two species.

The carapace and plastron of a large chelonian, which in its present broken condition measures 16 inches from side to side, is probably the *Enaliochelys* of Prof. Seeley.

Several large crocodilian teeth, mostly without fangs, and from 2 to 3 inches long, have the enamel smooth or finely granular, with a strong sharp keel up each side, which, when perfect, is seen to be finely serrated. All these teeth are lozenge-shaped in section; but some are much more rounded than others, and the points have in many cases been worn off during life. These teeth doubtlessly belong to *Dacosaurus*, (now referred to *Geosaurus*, Plieninger*), and under some of them I found a piece of paper with the following pencil-note :—"A new species of *Dakosaurus*, hereafter to be named *Dakosaurus Fisheri* (Seeley), a kind of crocodile allied to *Teleosaurus*, and to this animal belong the smooth teeth with a ridge on each side." This seems to be the form since called *D. lissocephalus* by Prof. Seeley, and now referred to *Geosaurus maximus*. A very ponderous ungual phalanx, 7 inches long, has a label giving it the name of *Gigantosaurus megalonyx*.

The remains of Fishes in this collection are not numerous; but some of them are interesting. Ganoids are represented by a lower jaw of *Gyrodus* and by some *Lepidotus* scales. Elasmobranchs (Sharks) are represented by *Asteracanthus ornatissimus*, of which there are several dorsal defences. There are a few spines of *Hybodus acutus*, some isolated teeth, and a very large example of the Hybodont defence, so long known as *Sphenonchus*; the base of this specimen is about 2 inches long and 2 wide, the external enamelled part is broken, and consequently one can only judge of its size by the extent of the part which remains, but this is very stout and shows that the external defence must have been large.

There are two large dorsal spines of *Hybodus*, which differ from those of any known species. The most perfect one has both ends a little broken; but in its present condition it is 12 inches long and about 1½ inches wide at the thickest part. The basal groove extends rather more than half the length of the spine. The sides of the exposed portion are ornamented with somewhat irregular, longitudinal ridges, broken up and varying in size, between which there are smaller and more irregular ridges. One strong ridge, extending along the anterior margin, forms a definite keel. The distal part of the posterior border is, as usual, furnished with strong

* *Lydekker*. Cat. Foss. Rept. Brit. Mus., pt. ii., p. ix. 1889.

denticles. I would suggest that this species be called *Hybodus Fisheri*, as a mark of respect for its owner, who has for so many years most zealously collected vertebrate fossils from the Kimeridge Clay of Ely.

In the following list of Fossils from the Kimeridge Clay of Cambridgeshire C. = Cottenham, E. = Ely, K. = Knapwell, W. = Willingham.
The authorities are as follows :—
(1) J. F. Blake, *Quart. Journ. Geol. Soc.*, vol. xxxi., pp. 201, 217–222.
(2) T. G. Bonney, Cambridgeshire Geology, p. 20.
(3) Geology of Cambridge, p. 10.
(4) T. Roberts, *Quart. Journ. Geol. Soc.*, vol. xlv., p. 558.
(5) G. Sharman and E. T. Newton.
(6) R. Lydekker, Catalogue of Fossil Reptilia, British Museum, Parts 1 and 2, 1888, 89.

Reptilia.

Cimoliosaurus (Plesiosaurus) trochanterius, *Owen* (P. macrodeirus, *Seeley*, Colymbosaurus megadeirus, *Seeley*)	E (1, 5, 6).
Geosaurus maximus, *Plien.* (Dacosaurus lissocephalus, *Seeley*)	E (1, 5, 6).
Gigantosaurus megalonyx, *Seeley* (MS.)	E (1, 5).
Ichthyosaurus chalarodeirus, *Seeley* (MS.)	(1, 6).
——— hygrodeirus, *Seeley* (MS.)	(1, 6).
——— trigonus, *Owen*	E (5, 6).
Metriorhynchus ?	(6).
Peloneustes æqualis, *Phil.* (Pliosaurus sterrodeirus, *Seeley*)	(1, 6).
Pliosaurus brachydeirus, *Owen*	E (1, 5, 6).
——— (Plesiosaurus) brachyspondylus, *Owen*	E (1, 5).
——— macromerus, *Phil.* (P. grandis, *Owen*)	E (5, 6).
——— nitidus, *Phil.*	E (5).
Steneosaurus	E (5).
Thallasemys Hughii, *Rütimeyer* (Enaliochelys chelonia, *Seeley*)	(1).

Pisces.

Asteracanthus ornatissimus, *Ag.*	C, E (2, 5).
Ditaxiodus impar, *Owen*	E (2), Wilburton.
Eurycormus grandis, *A. S. Woodw.*	E.
Gyrodus sp. (umbilicatus ?, *Ag.*)	E (2).
——— sp.	E (5).
Hybodus acutus, *Ag.*	E (5).
——— Fisheri, *Newton* (n. sp. see above)	E (5).
——— (Sphenonchus)	E (2, 5).
Ischyodus	E (2).
Lepidotus	E (2, 5).
Leptacanthus ?	E (2).
Macropoma substriolatum, *Huxley*	E (2), C.

Cephalopoda.

Ammonites alternans, *von Buch.*	E (4), W (5).
——— biplex, *Sow.*	E (1, 2), K (3).
——— calisto, *D'Orb.*	E (2).
——— cordatus, var. excavatus, *Sow.* (A. serratus, *Sow.*)	E (1).
——— eudoxus, *D'Orb.*	E (2).
——— longispinus, *Sow.*	E (1, 2).
——— mutabilis, *Sow.*	(1).
Aptychus (Trigonellites) latus, *Park.*	E (2).
Belemnites abbreviatus, *Mill.*	K (3).
——— explanatus, *Phil.*	E (2).

Gasteropoda.

Dentalium Quenstedti, *Blake* - - (1).

Lamellibranchiata.

Arca minuscula, *Cont.* - - - (1).
—— rhomboidalis, *Cont.* - - - (1).
Astarte ovata, *Sow.* - - - (1).
——— supracorallina, *D'Orb.* - E (4).
Avicula ædilignensis, *Blake* - - (1).
——— costata, *Sow.* - - - W (5).
——— echinata, *Sow.* - - - K (3).
——— inæquivalvis, *Sow.* - - - E (2).
Cardium striatulum, *Sow.* - - - E (1, 2).
Cucullæa (Arca) contracta, *Phil.* - - E (2).
Exogyra nana, *Sow.* - - - E (2), K(3), W(5).
——— virgula, *Defr.* - - - E (1, 2, 4).
Gastrochæna? - - - W (5).
Lucina minuscula, *Blake* - - E (1).
Ostrea deltoidea, *Sow.* - - - E(2, 4), K(3), W(5).
——— gregaria, *Sow.* - - - E (2), K (3).
Pecten Grenieri, *Cont.* - - - (1).
——— lens, *Sow.* - - - - (1).
Trigonia clavellata, *Park.* - - - K (3).
——— Pellati, *Mun-Chal.* - - (1).

Brachiopoda.

Discina latissima, *Sow.* - - - E (1, 2).
Lingula ovalis, *Sow.* - - - E (1, 2).
Rhynchonella inconstans, *Sow.* - - E (1, 2).

Crustacea.

Pollicipes Hausmanni, *Koch* and *Dunk.* - (1).
Cytheridea Ruperti, *Blake* (MS.) - - (1).
——————— triangulata, *Blake* (MS.) - (1).
Cythere æqualis, *Blake* (MS.) - - (1).

Annelida.

Serpula tetragona, *Sow.* - - - (1).
——— variabilis, *Sow.* - - - W (5).
Vermilia sulcata, *Sow.* - - - W (5).
Vermicularia contorta, *Blake* - - E (1).

Echinodermata.

Rhabdocidaris maxima, *Goldf.* - - E (2).

Foraminifera.

Cristellaria lævigata, *D'Orb.* - - (1).
Marginulina gracilis, *Corn.* - - (1).
——————— lata, *Corn.* - - - (1).
Planularia strigilata, *Reuss.* - - (1).
Vaginulina harpa, *Roem.* - - - (1).
——————— striata, *D'Orb.* - - - (1).

CHAPTER III. CRETACEOUS BEDS BELOW THE CHALK.

Lower Greensand.

In the western part of our district the Lower Greensand occurs in a number of small tracts, of which four are outliers, whilst the six others, though separate as outcrops, probably join on to each other beneath the Fens, and also to the main mass south of the Ouse-marshes. The formation is, however, so thin that possibly it may be cut out in places, by the Gault overlapping on to the Kimeridge Clay, near Barraway being a likely locality for such an occurrence.

The Lower Greensand consists of sand, brown and light-coloured, but rarely green, with sandy clay; the only point of interest perhaps being the occurrence of rolled phosphatized nodules and fossils (derived from Jurassic beds), which have been worked in several places by the edge of, or just beneath, the Fens.

Main Mass.

The outcrop on the south of the Alluvium of the Ouse has already been described, in the Cambridge Memoir. The nearest point to this at which the Lower Greensand was seen was at some coprolite-workings, under the fen on the southern bank of the Ouse about a fifth of a mile below Stretham Ferry Bridge; but there was no good section at the time of my visit, in 1882, when I was told that coprolites had also been worked a little to the S.W.

In a ditch on the north I saw a little peat, &c., not over 2 feet thick anywhere and often less, resting on light-coloured Kimeridge Clay. Close by, to the south, the Lower Greensand comes on, beneath the Alluvium, in hollows, and consists of clayey sand and very clayey greensand, with the nodule-bed, up to 9 inches thick. There were pieces of iron-sandstone as well as of sandstone. The owner told me that he had sunk to a depth of 10 feet here. The irregularity of the junction with the Kimeridge Clay was shown by this clay occurring in sharp humps: *Ammonites biplex* was common in it.

Another old working, on the northern side of the river nearly a mile N.E. of the bridge, had, I was told, extended over seven acres, to a depth of 2 feet; but, as the Kimeridge Clay seems to crop out all round, this would seem to have been merely in a set of pipes, or in a sheet of nodules left from the erosion of the Lower Greensand.

An old working was seen, on the northern bank of the river, about three quarters of a mile below the bridge, and, at an earlier date, Mr. Skertchly saw another about an eighth of a mile further.

Up to this point no Lower Greensand has been shown on the map; but from here (southward of Stretham) there is a small outcrop, by the side of the left river-bank, for less than a quarter of a mile. I mapped this little patch in 1882, but with some doubt, the boundary being taken from a slight rise of the ground. There is sandy clay about, and the nodules have been worked at the western end.

On the other side of the river a low mound rises from out of the Alluvium, eastward from Mere Mill, forming an island in the marsh, with a loamy soil. On the river-bank, at the north-western part, green sandy clay was seen, and at the north-eastern, sandy clay.

Mr. Skertchly saw a coprolite-working by the left side of the Ouse just below Stretham Common, and he has left the following note of one "near the confluence of the Ouse and the Cam, close to the former," taken in 1873 and partly printed in the Fenland Memoir, p. 253:—

Alluvium - { Peat, 2 to 3½ feet. / Light-blue and brown sandy loam, with roots of reeds, &c., 2½ feet.
Lower Greensand. Coprolites in a sandy matrix, appearing as a fine gravel, about 1½ feet.
Blue Kimeridge Clay.

A note, by the same observer, a year later, of coprolite-workings south of Thetford, referring either to the above or to a neighbouring section, gives the peat a thickness of 4 feet, the underlying light-blue clay, with carbonaceous markings, one of a foot, and the nodule-bed of about 20 inches. The last bed, like the others, was crowded with fragments of roots, with which vivianite (blue phosphate of iron) was plentifully associated.

From this part the Lower Greensand rises up westward, from beneath the fen, and forms a long spur, over the higher ground, by Stretham, Wilburton and Haddenham, to Aldreth, which is the largest area of the formation in our district, there being but little capping of newer beds.

Phosphatic nodules occur along the border of the fen, and the following notes were taken by Mr. Skertchly in 1874:—"Just west of Plantation House, east of Stretham, dark brown fine sand, with pieces cemented into hard masses, was seen, in 1874; but the section was obscure. Though phosphatic nodules were dug close by but few were seen in the sand here. There is a strong spring, and two hollows seem to indicate old sand-pits."

"The excavations for the phosphatic nodules were closed, and no trace of them could be made out. Some mounds of the sortings were lying in the farmyard, and the material was seen to consist of pebbles (quartzite being abundant), many fragments of ironstone and pieces of the fine conglomerate caused by the cementing together of the pebbles. The shining black siliceous pebbles so characteristic of these beds were in plenty, as also rolled Brachiopods and fragments of Ammonites. Some of the pebbles were embedded in clay, mottled blue brown and purple."

In 1882 I saw an old nodule-working at the southern end of the little spur of the formation south-westward of the House, and Mr. J. J. H. Teall has given the following section of a working at Stretham *:—

Sand and pebbles (Drift), 4 feet.
[Lower Greensand.] { Loose sand, 3 feet. / Hard sandstone, 2 feet. / Coprolite-bed.

The following section, from the same authority, must have been in Wilburton, the place next westward of Stretham, though described as "at Haddenham, one mile to the west of Stretham":—

[Lower Greensand.] { Light-brown sands, 6 feet. / Small pebbles and nodules, 6 inches. / Sands, more or less indurated, 4 feet.
Kimeridge Clay.

Of a pit half a mile S.E. of Haddenham Church, Mr. Skertchly gives the following note, written in 1874:—

"Fine, clean yellow sand, irregularly bedded and finely current-bedded, was dug, in 1874, to the depth of about 15 feet. In some of the thinner

* The Potton and Wicken Phosphatic Deposits, p. 24. 8vo. *Cambridge* and *London*, 1875.

beds a few small pebbles occurred, and there was one regular continuous pebble-bed. At the base the sand was pebbly and cemented into a soft grey conglomerate. Throughout concretions of ochreous matter occurred, which, on the surface and in rabbit-holes, formed stalactitic masses, adhering to the sides. About 8 feet from the top was a layer of blue clay, about an inch thick, and ferruginous matter formed a continuous band, a quarter of an inch thick, both above and below this. There seemed to be a very slight north-easterly dip, not more than half a degree. The Kimeridge Clay seemed to be about 10 feet down, judging from a well at the bottom of the pit."

By some slip PROF. SEELEY has described the Haddenham mass as *Upper* Greensand.*

Turning now to the right, or eastern, bank of the Cam our most southerly outcrop is both very short and very narrow, yet this small piece of the western flank of the gentle Upware Ridge is of great interest, for here the Lower Greensand, which has been laid open in coprolite-workings, is banked against the Coral Rag at the surface, the two being separated by only a very small amount of Kimeridge Clay, westward of the Coral Rag outcrop.

This small outcrop has a considerable literature, and, as the sections have been for some time abandoned, we must depend chiefly on published accounts, as indeed MR. TEALL was obliged to, before 1875.

The first observer to describe these sections was MR. J. F. WALKER, from whose paper the following remarks are taken†:—

"The workings are situate about a mile from Upware" . . [N.] "The bed differs from the "Sandy conglomerate bed," in being less ferruginous, and containing more lime, probably derived from the Coral-line Oolite. The nodules are mixed with pebbles . . . about a third part is waste. . . The sections exposed by the workings differ considerably; the best I have seen was" . .

	Ft.	In.
Black peaty soil, often with bones of red deer, horse, &c.	1	6
Light-coloured coprolites	1	0
Sand, called silt by the workmen	1	6
Dark coprolites	0	9
Silt	1	6
Dark coprolites	1	0
Clay, not pierced [Kimmeridge (p. 310)].		

"At another working"—

Sand	6	0
Coprolitic vein	2	0
Conglomerate (hard rock)	0	4
Light-coloured sand and clay.		

"The three layers of nodules noticed in the first section often become blended into one, but the top layer differs in the nodules, being of a much lighter colour, and . . . less valuable."

"The hard rock (conglomerate), consisting of nodules and pebbles cemented together by carbonate of calcium, varies considerably, some-

* *Geol. Mag.*, vol. ii., p. 530. (1865.) Rightly as Lower Greensand on the following page.

† *Geol. Mag.*, vol. iv., pp. 309, 310. (1867.)

times being so firm as to be penetrated with difficulty; at other times the coprolites near the clay are easily worked . . Among the nodules there are found phosphatic shells . . They consist of fragments of Ammonites, (and some of the nodules are marked by impressions of Ammonites) casts of brachiopoda, conchifera and gasteropoda, also remains of large Belemnites and *Gryphæa dilatata*, composed of carbonate of calcium, occur, derived from the Oxford Clay."

In a short later account Mr. Walker notes that "the shells, &c., proper to the deposit are found more abundantly at the base," and that "most of the sponges that occur at Farringdon are found in this deposit."*

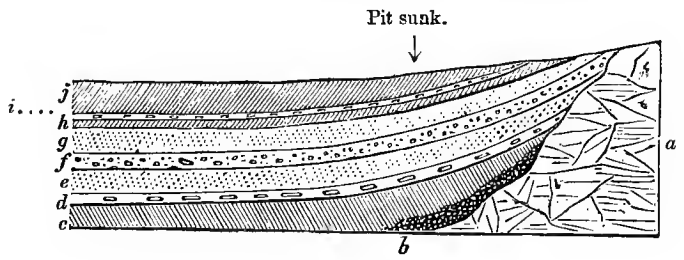
In the following year Mr. H. Keeping gave some further particulars,† and for his section, Fig. 1, we are indebted to the courtesy of the Editor of the Geological Magazine, Dr. H. Woodward. Our author says, believing that Gault occurred, at a short distance from the outcrop of the Coral Rag, "I sunk a pit. After passing through about seven feet of clay I came to a phosphatic bed, from which I collected the following fossils, proving, I believe, the whole to be Gault":—(*Ammonites interruptus, Amm. serratus, Baculites, Belemnites attenuatus, B. minimus, Dentalium ellipticum, Nucula ovata, N. pectinata.*)

"The pit was sunk about ten feet in depth." . .

"It will be seen from the section (fig.) that the Kimmeridge Clay is unconformable to the Coral-rag; and it would appear that, at the time of the deposition of the Kimmeridge Clay, a quantity of its [= Cor. Rag] broken and often rounded fragments became intermixed with it" [= Kimeridge Clay].

Fig. 1.

Section north of Upware. (H. Keeping.)



Gault.
- *j.* Non-fossiliferous Gault, 7 feet.
- *i.* Phosphatic bed, averaging 5 inches.
- *h.* Non-fossiliferous Gault, about a foot.

Lower Greensand.
- *g.* Upper layer of Lower Greensand (after 2 feet in Lower Greensand water stopped the work).
- *f.* Upper phosphate-bed of Lower Greensand.
- *e.* Lower Greensand, with few or no fossils.
- *d.* Lower phosphate-bed of Lower Greensand, rich in fossils, often cemented to hard conglomerate, and with many derived fossils.

c. Kimmeridge Clay.

Coral Rag.
- *b.* Coral Rag mixed with Kimmeridge Clay. Extends as high up as the deposit marked *h*, though not so shown in the figure.
- *a.* Coral Rag.

Some years later Prof. Bonney gave an acconnt of the sections here, from which the following description is taken‡:—

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* Lycett's Monograph of the British Fossil Trigoniæ, no. iii., p. 145. *Palæontograph. Soc.*, 1875.

† *Geol. Mag.*, vol. v., pp. 272, 273. (1868.)

‡ Cambridgeshire Geology, pp. 64–67. 8vo. *Cambridge* and *London*, 1875.

"An excavation which I examined in 1871, a short distance from the Coral Rag pit, gave the following section":—

		Ft.	In.
Top earth		0	6
Brown clay, probably re-arranged		2	0
Phosphate bed, probably washings from Gault and Neocomian beds		2	10
Gault.	Clay, with large fragments of fossil wood	4	6
	Phosphate bed. The clay below this, in Mr. Keeping's section, missing, or not distinguishable from the bed below	0	10
Neocomian [Lower Greensand].	Clayey sand	0	5
	Phosphate bed	0	6 to 7
	Sand	1	0
	Phosphate bed and conglomerate. Not exposed, but described by the workmen	1	3
	Sand.		

"The following year, a short distance more to the north, and rather higher up the slope—that is nearer to the terrace of Coral Rag—I saw the following section":—

Sandy soil.		
[Gault.]	Gault. Clay, with uneven base Passage bed. Clay mixed up in most complicated manner with pebbly and clayey sand, base very uneven	About 5 feet.
Neocomian [Lower Greensand].	Sand, at thinnest, about 15 inches.	
	Phosphate bed, 4 to 6 inches.	
	Sand, 15 inches.	
	Phosphate bed and conglomerate, forming floor of pit.	

"In another cutting about five yards off the Gault was rather more distinct from the clayey sand. It contained phosphatic nodules, and many characteristic fossils. This section appears to show that the passage from the sands of the Neocomian to the clay of the Gault, was marked by much local erosion."

"Again, in the year 1873, at a working about 200 yards north of the Coral Rag pit, and only a short distance from the lane (by side of which this rock seemed to be exposed in a ditch), I observed the following section":—

		Ft.	In.
Rather sandy soil		about 2	0
Gault. Clay, with phosphate nodules, base irregular. Fragments of *Ammonites*, 2 species of *Belemnites*, *Inoceramus concentricus*, *Plicatula*, and *Neithea*,		at most about 2	0
Neocomian [Lower Greensand].	Clayey brown sand	about 6	0
	Pebbles (some subangular), mostly of dark ferruginous sandstone (Neocomian), with occasional fragments of limestone (Coral Rag ?), 8 to 18 inches		
	Yellow sand, less clayey than that above		
	Phosphate bed; the nodules mixed with small pebbles of various rocks (chiefly of a brown cherty rock); from 8 to 12 inches, but irregular		
	Yellow sand, forming the floor of the pit. The workmen exposed and described the beds below	0	9
	Conglomerate, few phosphate nodules	0	6
	Black phosphate nodules	3	5
Dark clay, like Kimeridge Clay.			

The author then draws the following conclusions:—

The Lower Gault, with phosphate-nodules at its base, is in place, and its junction with the Neocomian is an unconformable one.

"The Kimmeridge Clay comes just below the lower [of the nodule-beds] so that the whole thickness of the Neocomian . . . does not exceed about eight feet."

"The Kimmeridge Clay must have formerly rested upon a most irregular base of Coral Rag, the surface of an old reef, and was denuded before the deposition of the Neocomian beds: so that in all probability a portion of the reef, which had been buried under a considerable thickness of clay, was again laid bare, as the level of the top of the clay which yet remains is rather below the top of the Coral Rag."

"The re-appearance of the Lower Gault on the west side of the reef is probably due to the flexure which has caused the dip of the Coral Rag; but I think that the dip of the Neocomian beds is partly one of original deposition."

Prof. Bonney then says that "the Neocomian fossils [*see* p. 31] are mainly confined to the lower phosphate bed, and I am inclined to think are rather local in it. The calcareous cement is derived from the neighbouring Coral Rag. . . . The abundance of terebratula with its allied forms and of sponges . . . suggests the probability that they clustered about the old reef, as the brachiopods, &c. now do on the Australian coast."

The same year Mr. Teall referred to the sections,* and gave the following further particulars:—

"The nodules are of two colours, light and dark; the former resemble those of Potton, the latter are characterized by a smooth exterior and a smaller percentage of phosphate. All the black nodules are bored by Modiolæ, and most of them are portions of derived fossils. As at Potton we frequently find ferruginous sandy nodules containing casts of fossils, which seem to have been derived from Neocomian strata." . . .

"The included pebbles are very similar to those at Potton. . . . I take it that many of these pebbles have been derived, as pebbles, from pre-existing Neocomian strata." . . .

"The indigenous fossils . . . are abundant, and are preserved in calcite." . . .

Nearly "all the ferruginous shells of Potton are found in calcite at Wicken [= Upware]. This fact, taken in connection with the stratigraphical relations . . . is quite sufficient to prove the approximate contemporaneity of the two deposits." . . .

"The sponges are all of Farringdon species."

"In general, then, we conclude that the Potton and Upware beds are the equivalents of the Folkestone beds of the south of England."

In this essay a list of the derived fossils is given, some of these being from older Neocomian beds, but most being of Jurassic origin.

Mr. Jukes-Browne, who saw the section with Prof. Bonney in 1871, and again in 1874, suggests that the clay at the top, in which no Gault fossils were found on either occasion, may have been an interbedded mass in the Lower Greensand; for like clays occur in the Lower Greensand between Thame and Aylesbury, some of which were formerly taken for Gault.

In 1877 Prof. Bonney remarked that "at the present time there is a considerable patch of the base of the Gault laid bare, just west of the south end of the [southern] Rag-pit, and perhaps four yards below the crest of the limestone."†

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* The Potton and Wicken Phosphatic Deposits, pp. 12–15. (1875.)

† *Geol. Mag.*, dec. ii., vol. iv., p. 476.

In 1873 Mr. Skertchly made the following notes (now first printed) of the section of the coprolite-works, but without marking the precise spot:—

		Feet.
Peaty soil		2
[Gault?].—Yellow clay		2
[Lower Greensand.]	Greenish sand	3
	Gravelly bed	½
	Sand	¾
	Coprolite-bed	1½
	Sand	over ½

"More to the north clay [Kimeridge] was touched beneath the coprolite-bed. The men said that to the south they found white stone, full of coprolites, at the top, and they described this bed as being like that in the pit [Rag-pit]. At the spot in question fragments of this rock were lying about, and consisted of unmistakable Coral Rag, with black coprolites of the ordinary character. Can it be a reconstructed bed? Was it in place? Do coprolites occur in the Coral Rag? In the last case it would be a remarkable coincidence that they should abut against the Cretaceous coprolite-bed; and I incline to the opinion that the deposit is reconstructed, the oolitic grains, &c. having been washed into the coprolite-bed and then cemented together."

The latest account of these Upware sections was written by the late Mr. W. Keeping, from whose book some remarks will now be taken.*

As noted by this author his section, which is here reproduced, is in the main similar to that of his father, given above, p. 23, and the same reference-letters have therefore been adopted here for all the beds.

The Lower Greensand has also been found in coprolite-workings beneath the Fen eastward of the Upware ridge. Mr. W. Keeping noted the following section in 1879 as at "new pits close to a farm some 500 or 600 yards east of the Spinney Abbey Farm."†

[Surface-beds.]	Brown surface-earth; 1½ feet. Head of blue clay; 9 inches. Irregular gravelly bed, pebbles mostly flints and coprolites; 3 inches.
Lower Greensand.	Blue, yellow, and coarsely mottled clay, with scattered coarse grains of quartz, ironstone, &c., and many irregular nodules of coarse ferruginous sandstone and some fibrous wood: passes down into the next; 2 feet. Brown and yellowish sand, passing into sandy clay, rather coarse and loose: consists chiefly of grains of quartz and of ironstone, with a few ferruginous nodules: passes down into the next; 2 feet. Phosphatic nodules and pebbles of Lydian stone, chert, quartz, &c., in loose iron-coloured sand: some ferruginous concretions in the upper part; 2 feet. Phosphatic nodules, darker than those above, in a sandy matrix, hardened almost to a rock by carbonate of lime; 3 inches.
Corallian.	Hard grey gritty bedded limestone, with scattered large oolitic grains.

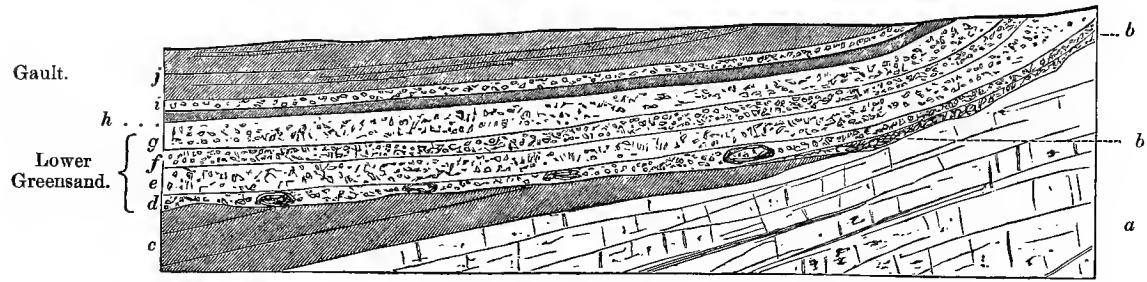
* The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill. 8vo. *Cambridge*, 1883. (pp. 3–7.)

† The Fossils . . of . . Upware, &c., pp. 7, 8. (1883.)

FIG. 2.

The Upware Section. (W. KEEPING.)

Given through the courtesy of the Authorities of the Cambridge University Press.



Gault. { *j.* Unfossiliferous Gault ; 7 feet.
i. Phosphate nodule-bed, rich in fossils ; 5 inches.

An unconformity is said to occur here, though the figure does not bear it out, and the next bed seems as likely to belong to the Gault (to which it was at first referred) as to the Lower Greensand. Probably, had the author lived, he would have modified the statement, and his father (MR. H. KEEPING) writes to me that there is no evidence of unconformity.

Lower Greensand, about 12 feet. {
h. Clay ; about a foot.
g. Sand, or yellow silt.
f. Nodule-bed, with pebbles as in *d.*, loose : yielded many Brachiopods.
e. Sand, or yellowish silt (grains of quartz, Lydian stone, chert, and ironstone).
d. Sand, with phosphatic nodules and various pebbles (chert, Lydian stone, quartz, quartzite, jasper, and, more rarely, Coral Rag), fragments of ironstone, of iron-sandstone, and some of fine sandstone ; sometimes cemented, by carbonate of lime, into conglomerate : from this many of the best fossils were got.
b. Junction-bed of Lower Greensand. Coral Rag fragments in a paste of Kimeridge Clay.
}

Unconformity, here clearly marked.

c. Kimeridge Clay, apparently conformable to the next below.

a. Coral Rag.

For a list of the fossils, *see* pp. 31, 32.

As to the clay next above the sand, although Mr. Keeping had "no hesitation in referring this bed to the Lower Greensand," yet there may be a possibility of its being Gault, which seems to have been found elsewhere, judging by my recollection of sections seen, and by the next note.

In 1880 and 1881 Mr. H. B. Woodward noted the following section, nearly half a mile north-eastward of Spinney Abbey, at the only pit then open:—

Alluvium { Peaty mould / Yellow clay } 3 to 4 feet.
Gault. Pale greenish or bluish clay, with "race;" 3 to 4 feet.
Lower Greensand. Brown pebbly gravel and sand. Phosphatic nodules make up about half of the stones; amongst the rest are ironstone, calcareous conglomerate, Lydian stone, quartz, and grit; 2 to 3 feet.

Eastward of Barraway the Lower Greensand rises up from beneath the Fen, and caps the Kimeridge Clay, forming, with a little Gault and Boulder Clay, Haney Hill. Mr. Skertchly noted, in 1874, that "four chains west of the bridge over the Soham Lode at Haney Hill light-reddish-brown fine sand was seen, by the side of the road, to a depth of 4 feet, and further westward [north-westward ?], opposite the road to Barraway, a like section occurred."

He thought that the sand seemed to end abruptly, against Kimeridge Clay, in the Soham Lode, as if faulted, and he was inclined to map a fault, from about a third of a mile N. of Fordey north-eastward, between Barraway and Haney Hill, and west of Delph Bridge.

At Soham Causeway, Crooked Drain, Mr. Skertchly recorded the following section, also in 1874:—Peat, 2 feet; Sand (Lower Greensand), a foot; Kimeridge Clay.

Several years later I learnt that a few coprolites had been worked, both on the northern and on the southern sides of the road at the western part of this outcrop.

Outliers.

The scattered phosphatic nodules that occur in the fields on the low ground, on either side of the high road, about a mile south-eastward of Stuntney, seem hardly to justify the mapping of Lower Greensand there. Besides these there are also traces of sand, on the south-west; so that probably the Lower Greensand must have come on there when the ground had been but little less lowered by erosion.

At Lay Clerks Farm, south-eastward of Stuntney, there is a trace of sand, and Mr. Skertchly saw the phosphatic nodule-bed there.

In a drain north-eastward of Norney, parallel with the wood, I saw traces of the nodules on Kimeridge Clay.

Immediately east of the village of Stuntney the hill is capped by sand.

A small patch has been mapped, by Mr. Skertchly, on the top of Thorney Hill.

The only important outlier is at Ely, where the Lower Greensand occurs over the high ground, toward Witchford and Thetford for a distance of about 1½ miles from the cathedral, and in the other direction (north-eastward) for probably a shorter distance, the northern boundary being hidden by the Boulder Clay that comes on about half a mile from the cathedral.

Mr. Skertchly seems to have thought that the sand might extend a good way further, beneath the Boulder Clay, than has been shown on the map.

The eastern end of this mass is in the Great Roslyn pit.

Mr. Skertchly has left the following notes :—

"A few phosphatic nodules occur, scattered over the surface of the land, on the eastern side of the road to Cambridge, where the boundary-line crosses the road, S.S.W. of Ely."

"Further north, by the 66th milestone, there was a small pit (in 1874) in fine sand, red at top, but yellowish at about a foot down."

"The pond at the angle of the fence (marked on the map) about a third of a mile west of the 66th milestone is at the junction with the Kimeridge Clay, and light-brown phosphatic nodules occur in the clay turned out; but they probably come from the base of the sand."

"Three quarters of a mile a little S. of W. from the cathedral, there have been extensive pits, but they were disused and overgrown in 1874. Fragments of a hard rock, two feet thick, were still to be seen: it consists of sandstone, with a few small polished black and brown quartz pebbles, the middle part full of larger but like pebbles, and I was told that it had been found 4 feet thick. It is, however, very varying, for, on the same horizon, may be found loose sand with pebbles, the bed not having been consolidated."

"The south-western part of the cemetery, N.E. of the city, has been dug out, in parts to the depth of 12 feet, when Kimeridge Clay is touched. The Lower Greensand contains ferruginous sandstone, said to be 2 feet thick. What seems to be Boulder Clay (from the description given) comes on above."

Of this Ely outlier Mr. Teall says :—"On the south side of the road leading from Roslyn Hill pit to the town, the following section may be seen" :—*

Drift with flints, &c., 3 ft. .

[Lower Greensand.] { Decomposed sandstone, 1 ft. / Light brown sandstone, with small pebbles, 1½ ft. / Reddish sand.

Kimeridge Clay.

Fossils.

Our knowledge of the Lower Greensand fossils of Upware being so greatly derived from Mr. W. Keeping's work, it will be well to quote therefrom (pp. 8, 9, 31, 16–20). Palæontologists working at this bed must, of course, use Mr. Keeping's Essay.

He says :—"The fossils of the Upware and Brickhill Neocomians are preserved, for the most part, in calcite, the mineral being, in some of the zoological groups distinctly crystalline; some few organic structures have been replaced by limonite, and fossil wood occurs in the usual silicified condition. Of other fossils only the inside moulds and external casts are known, those being formed of ferruginous sandstone, limonite, and phosphate of lime."

* The Potton and Wicken Phosphatic Deposits, p. 23. 8vo. *Camb.* (1875).

"It is of the first importance at once to divide the fossils of these rocks into two great groups. All those which are mineralised in phosphate of lime, together with many of those in limonite are '*derived*' *fossils*" (as distinguished from the *indigenous* or *native* species).

"This separation of the fossils . . is, as a rule, . . easy . . for the *derived* fossils besides being characterised by the materials in which they are preserved, belong mostly to Jurassic species, and they occur usually as internal moulds which have been mutilated by attrition as they were rolled into pebbles during long years of wear and tear upon the ancient sea-beach."

The phosphatic nodules have been "much tunnelled by numerous boring organisms. These stone-borers were for the most part sponges, worms, and bivalve shells," especially the last.

"The derived fossils belong to various ages, ranging at least from the Neocomian to the Oxford clay inclusive." For an exhaustive account of them the reader is referred to Mr. Keeping's book.

Turning to the Indigenous Fauna Mr. Keeping notes that there are 151 species.

"The most striking features of the bed are the magnificent developments of the Lamp shells, or Brachiopoda, and its exceeding richness in large cup sponges, and massive and dendroid Polyzoa."

The native vertebrates are not abundant, and there is a difference of opinion about many of these, which have been thought to be really derived fossils.

"Of the *Cephalopoda* we have but very scanty representatives," and "specimens are rare of all the species." . . .

"Of *Gasteropoda* there are 16 species," mostly undescribed.

"Of *Lamellibranchiata* the *Ostreidæ* are conspicuous, as presenting the most striking forms and being the most numerous in individuals. . . The great resemblance of the Upware oysters to those of the Jurassic rocks is very remarkable. . . The special development of the Arcadæ . . is also noteworthy."

Fossils of the Lower Greensand of Upware.

From Mr. W. Keeping's work, The Fossils . . of Upware, . . 1883.
By some observers the Remains of Reptiles and of Fish are thought to be mostly *derived*.

Reptilia.

Crocodilian teeth and fragments of bone.	Iguanodon.
Geosaurus (Dacosaurus).	Plesiosaurus.
Ichthyosaurus.	Pliosaurus?

Pisces.

Acrodus.	Otodus or Oxyrhina (teeth and vertebræ).
Asteracanthus.	Pycnodus Couloni, *Ag.*
Gyrodus.	Sphærodus neocomiensis, *Ag.*
Hybodus (with Sphenonchus).	Strophodus.
Ischyodus Townsendi, *Buckl.*	

Cephalopoda.

Ammonites cornuelianus, *D'Orb.*
—— Deshayesii, *Leym.*
—— sp.
Ancyloceras Hillsii, *Sow.*
Belemnites pistilliformis, *Blainv.*
—— subfusiformis, *D'Orb.*
—— upwarensis, *Keeping.*

Gasteropoda.

Cerithium marollinum, *D'Orb.*
—— neocomiense, *Forbes.*
Litorina cantabrigensis, *Keeping.*
—— upwarensis, *Keeping.*
—— varicosa, *Keeping.*
—— sp.
Nerinæa tumida, *Keeping.*
—— sp.
Patella.
Pleurotomaria gigantea, *Sow.*
—— Renevieri, *Keeping.*
Scalaria Keepingi, *Gardn.*
Tessarolax Gardneri, *Keeping.*
Tridactylus Walkeri, *Gardn.*
Trochus, n. sp.
Turbo Reedi, *Keeping.*

Lamellibranchiata.

Arca Carteroni, *D'Orb.*
—— marullensis, *D'Orb.*
Astarte subdentata, *Röm.*
—— sp. and new sp.
Avicula cornueliana, *D'Orb.*
? Avicula, sp.
Cardita rotundata, *P.* and *R.*
Cardium cottaldinum, *D'Orb.*
—— subhillanum, *Leym.*
Cucullæa subnana, *P.* and *R.*
—— sp.
Cypricardia arcadiformis, *Keeping.*
—— squamosa, *Keeping.*
—— striata, *Gein.*
Cyprina angulata, var. rostrata, *Sow.*
—— obtusa, *Keeping.*
—— Sedgwickii, *Walker.*
Exogyra Couloni, *D'Orb.*
—— tombeckiana, *D'Orb.*
Gryphæa dilatata (?), *Sow.* (? derived).
Lima farringdonensis, *Sharpe.*
—— longa, *Röm.*
Lithodomus.
Modiola obesa, *Keeping.*
Modiola pedernalis, *Röm.* ?
—— sp.
Neithea atava, *Röm.*
—— Morrisii, *P.* and *R.*
—— ornithopus, *Keeping.*
Nucula subtrigona, *K.* and *D.*
Opis neocomiensis, *D'Orb.*
Ostrea frons, *Park.*, var. macroptera, *Sow.*
—— Walkeri, *Keeping.*
Panopæa gurgitis, *D'Orb.*
—— plicata, *Sow.*
Pecten Dutemplii, *D'Orb.*
—— orbicularis, *Sow.*, var. magnus, *Keeping.*
—— raulinianus, *D'Orb.*
Pectunculus marollensis, *Leym.*
—— obliquus, *Keeping.*
—— sublævis, *Sow.*
Pholas (Fistulana) constricta, *Phil.*
Plicatula Carteroni, *D'Orb.*
—— equicostata, *Keeping.*
? Thracia or Tellina.
Trigonia upwarensis, *Lyc.*

Brachiopoda.

Rhynchonella antidichotoma, *Buv.*
—— cantabrigensis, *Dav.*
—— depressa, *Sow.*
—— latissima, *Sow.*
—— upwarensis, *Dav.*
Terebratella Davidsoni, *Walker.*
—— Fittoni, *Meyer*, var.
*—— Menardi, *Lam.*
Terebratula capillata, *D'Arch.*
—— Dallassii, *Walker.*
—— depressa, *Lam.*, vars. cantabrigensis, *Walker*, cyrta, *Walker*, and uniplicata, *Walker.*
—— extensa, *Meyer.*
Terebratula Lankesteri, *Walker.*
—— Meyeri, *Walker.*
—— microtrema, *Walker.*
—— moutoniana, *D'Arch.*
—— prælonga, *Sow.*
—— Seeleyi, *Walker.*
—— sella, var. upwarensis, *Walker.*
Waldheimia celtica, *Mor.* (?).
—— Juddi, *Walker.*
—— pseudojurensis, *Leym.*
—— tamarindus, *Sow.*, var. magna, *Walker.*
—— Wanklyni, *Walker.*
—— Woodwardi, *Walker.*

* Added from DAVIDSON, *Pal. Soc.*

Polyzoa.

Ceriopora (Echinocava) Raulini, *Mich.*
—— (Reptomulticava) mamilla, *Reuss.*
Entalophora angusta, *D'Orb.* ?
—— dendroidea, *Keeping.*
—— ramosissima, *D'Orb.*
Heteropora arbuscula, *Keeping.*
—— coalescens, *Reuss.*
—— major, *Keeping.*
—— ramosa, *Röm.*
Heteropora (Multicrescis) Michelini, *D'Orb.* (?).
—— —— sp.
—— (Nodicrescis) annulata, *Keeping.*
—— (Reptonodicrescis).
Melicertites upwarensis, *Keeping.*
Radiopora bulbosa, *D'Orb.* var.
Reptomultisparsa haimeana, *De Loriol.*
Semimulticava (Radiopora) tuberculata, *D'Orb.*

Annelida.

Serpula [Vermilia] ampullacea, *Sow.*
—— antiquata, *Sow.*
—— articulata, *Sow.*
—— gordialis, *Goldf.*
—— [Vermilia] lophioda, *Goldf.*
Serpula plexus, *Sow.*
—— rustica, *Sow.*
Vermicularia Phillipsii, *Röm.*
—— polygonalis, *Sow.*

Echinodermata.

Cidaris, sp. (and thorny spine).
Peltastes Wrightii, *Desor.*
Pseudodiadema rotulare, *Ag.*

Spongida.

Elasmostoma subpeziza, *D'Orb.*; (peziza, *Goldf.*)
Pachytilodia.
Raphidonema (Catagma) cupuliformis, *From.*
—— —— porcatum, *Sharpe.*
—— macropora, *Sharpe* (=Elasmostoma acutimargo, *Keeping*, not *Röm.*)
Tremacystia (Verticellites) anastomans, *Mant.*
—— —— annulata, *Keeping.*
—— —— clavata, *Keeping.*

Gault. (By A. J. Jukes-Browne.)

The Gault is only exposed at the surface over small areas, separated by tracts of gravel and alluvium. It is of course assumed to be continuous beneath these superficial deposits, but no line has been engraved on the map for its boundary beneath the Fens.

The Gault enters the district represented on Sheet 51, N.W., to the south of Cottenham. It then passes beneath a broad tract of river-gravel, but is exposed on the eastern side of this in a long strip between Waterbeach and Causeway End Farm. Thence it passes under the Fen to the south of Upware, the small patch of Gault to the west of the Coral Rag tract near Upware being probably an outlier.

The Gault reaches the surface again by Wicken and Soham, forming the horseshoe-shaped ridge which surrounds the plain of Soham Mere; but to the west and north of Soham it again sinks beneath the Fens.

It presents its usual character of a stiff bluish-grey clay, suitable for brick-making. It contains scattered phosphatic nodules, which are most abundant near the base; and its thickness at Soham is proved by borings to be about 90 feet (see p. 111).

The sections in the small tract of Gault north of Upware have been mentioned on pp. 23–25, 27.

The Gault has been worked for brick-making, beneath the fen, less than a mile a little E. of S. from Wicken Church (W. W.).

The only good exposure of Gault in this district was at a brickyard a mile west of Wicken Church. This was visited in 1880 by Mr. H. B. Woodward, who took the following notes:—"The yard is on the border of the Alluvium; the clay is pale bluish, of a lighter tint at top, and, according to the workmen, it is stronger (*i.e.*, stiffer) the deeper they go, the thickness of clay before reaching 'rock' being about 50 feet. Shells occurred in a vein at a depth of 8 or 10 feet." The Gault is worked beneath peat and alluvial silt (W. W.).

There was a brickyard by Horsecrofts, and nearly a mile a little W. of S. from Soham Church, another about half a mile north-west of the Church, and another by Soham Causeway, half a mile north-east of Soham Cotes.

The Gault was also seen in the railway-cutting by the last place (W. W. See p. 101).

On the western side of Soham Mere the Gault overlaps the Lower Greensand and rests directly on the Coral Rag, lapping over the northern point of the ridge and forming the low hill on which Fordey Farm stands. Mr. H. B. Woodward, who revised the mapping of this locality in 1881, made the following note:—"East of Fordey Farm, and close by the Alluvium, Gault is reached beneath peaty soil, and, according to the tenant, it had been proved to a depth of 20 or 30 feet hereabouts. On the higher ground above the farm stiff pale greenish clay was shown, for a foot or more, in ditches and drain-cuttings."

Two outliers have been mapped. One is a thin patch between the Boulder Clay and the Lower Greensand at Haney Hill, Barraway. The other caps the hill from Haddenham to Wilburton, and the following note has been left by Mr. Skertchly:—"In the fields about the sand-pit half a mile S.E. of Haddenham church (see p. 21) there is bluish clay, yielding *Belemnites minimus* and phosphatic nodules, which is probably Gault in place." (W. W.)

CHAPTER IV. CHALK.

THE classification of the Chalk adopted by the Geological Survey has been noticed on p. 3, and that classification is based on the occurrence of certain hard beds at definite horizons by tracing the outcrop of which beds a threefold division has been made, whilst in this and neighbouring tracts the lowest division is again divisible. The following description, to the end of the Middle Chalk, has been written by MR. A. JUKES-BROWNE.

LOWER CHALK.

General Description.

Three palæontological zones are recognisable in the Lower Chalk. It would, however, give a more accurate idea of the vertical succession if the Lower Chalk were described as consisting of two broad zonal divisions, bounded and limited by three well-marked lithological horizons. The district now treated of is a natural continuation of that described in the Memoir on the Neighbourhood of Cambridge (published in 1880), and the subdivisions of the Lower Chalk recognised in that area are as follows :—

Zone of *Holaster subglobosus.*	Belemnite Marls	about 4	FEET.
	Chalk of Cherry Hinton	,, 80	,,
	Totternhoe Stone	,, 15	,,
Zone of *Ammonites varians.*	Chalk Marl	,, 70	,,
	Cambridge Greensand	,, 1	,,
	Total thickness	170	,,

The Cambridge Greensand forms the base of the Chalk Marl, and rests on an uneven and eroded surface of the Gault. It is a marl so full of dark green grains of glauconite as to be more of a sand than a marl, and in this matrix are embedded the phosphatic nodules or "coprolites" which are so well known commercially. For a full account of this bed the reader is referred to the Memoir on the Neighbourhood of Cambridge.

The Chalk Marl is a firm greyish marly chalk, with enough clayey matter to form a tough rock, locally known as clunch. In the Cambridge Memoir this subdivision was classified as the zone of *Rhynchonella Martini*, but it has since been thought preferable to call it by the name of the prevalent Ammonite (*A. varians*), the range of which has proved to be more limited than was formerly supposed, and which is a common fossil of the Chalk Marl throughout its southerly range, whereas the

Rhynchonella, though generally present, is not always to be found.

The lower part of the Chalk Marl has a lumpy and somewhat nodular structure, the harder and tougher parts being surrounded by softer and looser marl. Grains of glauconite are visible in it for some height above the basement greensand: the large visible grains become fewer and fewer, but minute grains, visible only under the microscope, extend throughout. Chemical analysis shows that the lower part contains from 70 to 78 per cent. of calcium carbonate, with from 12 to 20 per cent. of insoluble siliceous matter, and a variable proportion of soluble iron and alumina (doubtless constituents of the glauconite-grains). The chief part of the siliceous matter probably exists in the form of clay, but the microscope shows that there is a small proportion of fine quartz-sand. The microscope reveals also that the calcareous matter consists partly of fine calcareous mud or powder, and partly of recognisable organic atoms, such as Foraminifera (entire and broken), with small fragments of broken shells, Echinoderms, &c.

The proportion of calcareous matter increases upward, and near Burwell the upper part is a tough blocky kind of chalk, with probably not less than 80 per cent. of carbonate of lime.

The Totternhoe Stone has generally been described as a brownish-grey *sandy* chalk, but microscopical examination shows that the roughness and apparent *sandyness* is really due to the quantity of comminuted shell-fragments which it contains; chemical analysis, too, shows that it is essentially calcareous, a sample of the Burwell stone, containing nearly 86 per cent. of calcium carbonate.

Its basement-bed is a remarkable stratum, consisting of hard grey gritty stone, full of green-coated phosphatic nodules, which vary in size from that of a pea to that of a walnut or small potato; this layer is a foot thick at Burwell, and is locally known as "brassil." It is persistent through Cambridgeshire, and probably through Suffolk and Norfolk. The mass of the stone occurs in thick beds, and cuts as a freestone, having an even grain, except that it contains numerous small broken bits of brown phosphate and many fossils. The highest bed at Burwell is a compact brownish-grey stone, rather harder than the rest, and known locally as the "bond" course; it is there about 3 feet thick, but appears to thin out northward. The stone is, in fact, very variable in thickness; at Burwell it is from 15 to 20 feet thick, but it thins northward till it is only 4 feet at Stoke Ferry, in Norfolk.

The minute structure of a typical sample of the stone is described by MR. W. HILL, as consisting of from 60 to 70 per cent. of shell-fragments, generally of very uniform size, as if sorted by current-action, many glauconite-grains, which are often large, and frequently in the shape of perfect casts of Foraminifera, with a small per-centage of fine quartz-sand.

The Totternhoe Stone generally passes up into a tough *Grey Chalk*, blocky, close-grained and destitute of glauconite-grains. At Cherry Hinton (south of our district) there is from 25 to 30 feet of such chalk, but at that height it passes rapidly into a hard white chalk, which breaks with a smooth clean fracture; this continues for about 20 feet, and passes up into softer and more marly chalk, which is whiter than that above the Totternhoe Stone. The total thickness near Cambridge is 80 feet, but it appears to decrease toward the north.

The harder white chalk is found on microscopical examination to contrast with that below in the absence of shell-fragments, and in the presence of a large number of the small spherical bodies which are regarded as the primordial or disunited cells of Globigerina; these are embedded in a fine white calcareous earth, and the rock is, in fact, a variety of foraminiferal ooze or chalk. The number of the spherical cells becomes much less in the higher beds.

At West Row, near Mildenhall, this division exhibits very abnormal lithological characters, and includes a band of reddish-pink chalk.

The *Belemnite Marls* consist of two layers of shaly marl, separated by a course of hard compact white chalk. The lower bed of marl is generally greenish-grey; the upper marl is yellowish or buff; fossils are not common in either, but *Belemnitella plena* occurs ocasionally, *Ostrea vesicularis* and *Rhynchonella plicatilis* more frequently. The white chalk splits with a smooth even fracture, and its structure resembles that of the white chalk in the zone below, single foraminiferal cells being scattered abundantly through a fine amorphous matrix.

Cambridge Greensand.

The Cambridge nodule-bed, which forms the base of the Chalk Marl, enters Sheet 51, N.W., beneath the Fen to the south-west of Reach and passes thence in a north-easterly direction beneath Burwell Fen.

The coprolites were formerly worked at several points between Reach and Soham, and some particulars of these have been given in the Memoir on the "Geology of the Neighbourhood of Cambridge."

The nodule-bed emerges from the fen at a point about five furlongs south-east of Wicken Church, and the outcrop then runs north-westerly to the church and thence for half a mile, when it bends north-easterly toward Horsecrofts, and is finally lost in the fen eastward of Soham.

Mr. H. B. Woodward found that the coprolites were being worked east of Wicken Church in 1880, and they have also been worked to the east of Horsecrofts, where the top three beds, noted under Well-sections (p. 111), were seen in the pits by Mr. Skertchly.

The outcrop by the Cherry Tree, south-east of Soham, is a little doubtful, but Mr. Skertchly has noted a well, a quarter of a mile eastward of

the house, in which "coprolites" were found at the depth of about 10 feet. Coprolites have been dug on the north-eastern side of Brook Street (Soham outlier) at a depth of 10 feet. The whole of the southern part of Soham in fact stands upon Chalk Marl, which, with its basement-bed, extends westward to within a furlong of the railway-station.

East of Soham the outcrop is concealed by gravel, but in 1872 Mr. Skertchly saw coprolites dug near Wedd's Farm, two miles north-east of Soham, below a few feet of gravelly soil and disturbed marl. This point is therefore close to the outcrop, and is at the same time the most easterly place to which the coprolites have been followed.

No evidence was obtained in the progress of the Survey with regard to the continuation of the bed to the north-east under the Fens; there can be little doubt, however, that the Cambridge Greensand, the noduliferous base of the Chalk Marl, preserves the same character for some miles further to the north-east, possibly as far as the northern edge of Sheet 51: but the probability is that the phosphatic nodules gradually decrease in number, so that beyond a certain point the seam would never be worth working for commercial purposes.

In the absence of evidence no line has been engraved on the map for the base of the Chalk Marl beneath the Fens, in Sheet 51, N.E., but as an aid to future exploration it may be stated that the outcrop of the coprolite-bed may be expected to run from near Wedds Farm in an easterly direction through Isleham Fen as far as the River Lark, and thence to the north-east through Mildenhall Fen and Lakenheath Town Moor. [If, however, the occurrence near Wedds Farm is part of the Soham outlier, rather than of the main mass the line may run from eastward of Soham, through the Fens in a north-easterly direction, to the Lark. On the other hand the Soham mass may join on beneath the fen to the main mass.—W. W.]

Chalk Marl and Totternhoe Stone.

The sections in the large quarries of Burwell have been described in the Memoir on the Neighbourhood of Cambridge, but the railway from Cambridge to Mildenhall was not made when that memoir was written; the following notes on the cuttings along this line have been placed at our disposal by Mr. W. Hill, who examined it in 1886.

"The entrance of the cutting immediately east of Burwell Station appeared to be in Chalk Marl, but the whole of it was faced and partly overgrown, and the only evidence obtainable was from the floor and from the heaps of débris at the base of the telegraph-posts, which presumably came from the holes dug for their erection; in these *Ammonites varians*, fragments of *Turrilites* (*costatus?*), and *Ostrea vesicularis* were abundant. A hundred yards further east Totternhoe Stone comes in and *Rhynchonella mantelliana* occurs in some quantity, with a few specimens of *Am. varians* and *Ostrea*. The eastern end of the cutting appears to be in Chalk Marl, but no fossils were found."

The cuttings along the Soham and Newmarket line, from near Soham to Landwade, were thought to be in Chalk Marl by Mr. Whitaker, and the outcrop of the Totternhoe Stone along this line was not ascertained. From Mr. Hills's notes, above quoted, it would appear that the Totternhoe Stone comes in with a synclinal, forming the ridge east of Burwell, and it thus appears probable that the low ground or Landwade valley coincides with an anticlinal flexure having a general north and south direction and bringing up the Chalk Marl.

The first point beyond Burwell where traces of the stone were observed was in the shallow cutting on the railway to Mildenhall, seven furlongs north of Fordham Station, where a plot of ground, between the road and the line, has been levelled, and shallow trenches have been dug to facilitate the escape of the water. From these excavations fragments of hard rocky material have been turned out, which resemble the "brassil" or basement-bed of the Totternhoe Stone, containing green-coated nodules and a few fossils, such as *Rhynchonella grasiana* and *Pecten fisicosta, P. quinquecostatus* and *Plicatula inflata*, and many small fish-teeth. It seems to crop out here with an easterly dip.

At Isleham there are two large quarries which have been worked for many years, and both expose sections of the Totternhoe Stone. That seen in the older quarry south of the church is as follows:—

	Feet.
4. Soil and rubble - - - - -	2 to 3
3. Firm greyish-white chalk - - -	6 to 4
2. Hard grey chalk, rather rough and mottled with patches of darker grey, in thin beds	2 to 3
1. Grey stone in massive blocks - seen for	6

The beds numbered 2 are termed "the hards" by the workmen, and they occupy the place of the "bond course" at Burwell, but are lithologically very different. The stone below is locally called "the blocks," and has the usual characters of Totternhoe Stone; its base is not seen, but the men state that there is similar stone for another 6 feet, a different bed being then reached which they call "the greys."

The other quarry is about a quarter of a mile east of the church and exposes a rather deeper section, but without showing the base of the stone.

The stone is constantly burnt for lime, but is also used for rough building and walling work when required. Mr. Whitaker notes that "it has been used in the construction of the church and in the old Priory barn, but not in the earliest work, which is of Barnack Stone. In modern times it has been used in the restoration of the church, some of the stone, however, having been brought from Burwell."

[The following information was given me in 1884 by Mr. W. Marshall, of Ely.—W. W.]—"I never could find anybody who had sunk through the Chalk at Isleham, and the reason assigned was that so much water came in. We have now made a boring in one of the pits, where the saturation-level is 21 feet from the surface, and we have gone down 55 feet lower than that level, without going through to the Gault, a greater depth than I expected. The lowest part of the boring showed the bottom chalk to be much fissured; so that the chisel went down 3 feet at a jump, shortly before the workmen gave over. I think that a very few feet more would have brought us to the Gault." (See account of well-section, p. 110.)

When examining the cuttings on the Cambridge and Mildenhall line in 1886, Mr. W. Hill found traces of the Totternhoe Stone in the cutting which commences 400 yards west of Isleham Station. He says:—"The entrance of the cutting is, I believe, in Chalk Marl, but about 50 yards from the end the Totternhoe Stone comes in, and the blocks of chalk seen in the middle of the cutting have a reddish-brown tint on the outside, the colour penetrating about half an inch into the block; the 'bond' rock in some of the pits at Burwell is stained in a similar way, so that

the top of the Totternhoe Stone may here be indicated. *Rhynchonella mantelliana* and *Ammonites varians* occur throughout the cutting, but most plentifully near the entrance. The dip appears to be steady to the eastward, and between the station and Beck Bridge (Freckenham) the cutting appears to be in the grey chalk which overlies the stone."

When driving through this district with Mr. Hill in 1886 we did not find any exposure of Totternhoe Stone near West Row, but a quarry more than three quarters of a mile northward of the ferry showed hard grey gritty stone in thin beds, which weathers into rubbly lumps; this is probably not far above the stone.

The clunch-pit, marked on the map, nearly a mile and a quarter northward of the ferry, is now disused and turned into a garden, but we found a small exposure of brownish-grey gritty stone, like Totternhoe Stone, an identification which was afterwards confirmed by microscopical examination. The slight feature made by the outcrop of the stone here can be followed as far as Beck Row, striking nearly N.N.E., but beyond that place the feature is obscured by the blown sand which overspreads so large a part of this district.

Zones of Holaster subglobosus and of Belemnitella plena.

The railway-cuttings west of Landwade are in grey chalk, but are now grassed over. Mr. Whitaker took the following notes of the cutting south-west of Snailwell:—"At the south-eastern end there is brown loam, which includes a seam of blackish earth and a whitish (calcareous) layer, and contains land and fresh-water shells: the upper part is stony (chiefly bits of chalk). This hardly reaches 30 yards, when white chalk rises up. Soon a pale greenish grey chalk comes on above the white, and then sinks to the bottom of the cutting, the level of which rises; this bed is hard, partly nodular, with the prismatic or so-called 'striated' structure, and it includes a marly layer. Further on there is a buff sandy layer (? washed in by infiltration from the surface) in this bed, which seems to run through the cutting, but it is whiter and more rubbly at the northern end. Above it there is hard rubbly chalk." The greenish grey chalk and marly band is probably the zone of *Belemnitella plena*, and the rubbly chalk would be the base of the Melbourn Rock. The engineer (Mr. Smith) informed Mr. Whitaker that a large Ammonite, 2 feet in diameter, was found in this cutting, and that boulders were found in the chalk.

There is a small pit north-east of Fordham which appears to be in the grey chalk just above the Totternhoe Stone, but no fossils were found, and the chalk is in a peculiar broken and lumpy condition.

Part of the railway-cutting near Isleham Station is in grey chalk, from which there seems to be a gradual passage downward into Totternhoe Stone.

Crossing the River Lark the first and most important section is that in the large quarry, nearly half a mile north-east of West Row Ferry. The remarkable bed of red chalk here exposed was described for the first time in 1887,* for so out of the way was this district before the railway to Mildenhall was constructed, that when Mr. W. Hill and the writer visited the quarry in 1886, one of the workmen said that we were the first strangers he had seen there, though he had worked in the quarry for 13 years.

The band of red marly chalk is seen near the entrance to the pit, dipping westward at a low angle, but soon becoming horizontal and running along the whole face of the quarry till it is cut off by a fault, which brings up lower beds on the southern side. The complete section

* *Geol. Mag.*, dec. iii., vol. v., pp. 24–28.

at the deepest part of the pit, not far from the entrance, was as follows :—

	Feet.
Soil and rubble of yellowish chalk	4
Pink marly chalk, becoming yellow above	3
Hard nodular grey chalk	2½
Grey shaly chalk	2
Very hard grey nodular chalk (*Ammonites Austeni, Belemnitella plena*, and *Terebratula semiglobosa*)	1
Thin-bedded whitish chalk	2½
Hard greyish chalk	2
Softer thin-bedded chalk (*Holaster subglobosus*)	6
Hard lumpy yellowish rocky layer	0½
Softer chalk below, according to the workmen.	

At the western end of the quarry the red band lies at a greater depth, and its full thickness is seen to be about four feet, the following succession being here visible in 1886, along a face running east and west.

	Feet.
Chalky soil	1
Rough yellowish chalk, much weathered and broken	4
Red chalk, soft and marly, brick-red at top weathering pink, lighter below	4
Greyish white chalk, marly and platy, with hard lenticular lumps	1½
Hard grey rocky chalk weathering into a rough nodular surface	2
Soft grey marly chalk, seen for	1½

The hard grey rock near the base of this section is certainly the same bed which directly underlies the red chalk in the eastern part of the pit, and the overlying white chalk is either a separate local bed, coming in westward, or it is a part of the band which is coloured pink to the eastward; it is similar in appearance to the pink chalk above it, and, as this has lumps which are whitish outside, the colouring stain may not have extended down so far at this point.

The western face (running nearly north and south) shows a fault, the succession above described being cut off abruptly against soft whitish chalk in thin beds, of which neither top nor bottom are seen, but which are probably thrown up, as the fault-plane hades northward, and they may be part of the six feet of thin-bedded chalk in the lowest part of the deepest excavation. The hard beds on the northern side of the fault curve up slightly toward the fault-plane.

The reddish-pink chalk breaks into small angular blocks, the edges of which are pinkish-white, and all the joint-planes which cross the bed are bordered by whitish bands about a third of an inch thick; facts which seem to indicate that the percolation of water from the surface has effected a certain amount of decoloration, and that the whole was originally of uniform colour. The tint is darkest at the top, and becomes lighter toward the base. There is a further change of colour near the outcrop, where the whole bed weathers into yellow rubble.

As the local dip of the beds here is westerly, there must be an anticlinal to the east of the pit, and a second outcrop, with an easterly dip, nearer to Mildenhall, but of this no traces were seen.

From the red band we did not obtain any fossils, but in the lower beds many have been found, *Holaster subglobosus* being fairly common and going far to establish the stratigraphical position of the beds in the face of their abnormal lithological characters. The occurrence of typical *Belemnitella plena* is particularly noteworthy, as such specimens have never yet been found at so low an horizon in the Chalk: the *Belemnites* referred to this species from the Totternhoe Stone of Burwell being really the *B. lanceolata* of Sowerby, and probably a distinct species.

Elsewhere *B. plena* has only been found in white chalk at the very top of the *Holaster subglobosus* zone, and in the marls which overlie this.

The chalk-pit a mile and a quarter north-east of Mildenhall, shows hard white blocky chalk similar to the higher part of that of Cherry Hinton, and there is no trace of anything like the peculiar beds of West Row. To the northward the country slopes gradually toward the fen, and the surface is occupied by blown sand.

Fossils.

Specimens of most of the fossils named below are to be found in the Woodwardian Museum, Cambridge, or at Jermyn Street; but a few were got only by Mr. Hill and myself.

In this list, I = Isleham, W = West Row.

—	Totternhoe Stone.	Grey Chalk.
Echinodermata.		
Discoidea cylindrica, *Lam.*	I	W
Holaster subglobosus, *Leske*	I	W
——— trecensis, *Leym.*	—	W
Crustacea, &c.		
Enoploclytia brevimana, *McCoy*	I	
Glyphæa cretacea, *McCoy*	I	
Pollicipes glaber, *Röm.*	I	
Scalpellum maximum, *Sow.*	I	
Vermicularia umbonata, *Sow.*	I	
Brachiopoda.		
Kingena lima, *Defr.*	I	
Rhynchonella Cuvieri, *D'Orb.*	—	W
——— mantelliana, *Sow.*	I	I. W
——— plicatilis, *Sow.*	—	W
Terebratula biplicata, *Sow.*	I	W
——— semiglobosa, *Sow.*	I	W
——— squamosa, *Mant.*	I	
——— sulcifera, *Mor.*	I	W
Terebratulina gracilis, *Schloth.*	?	
Lamellibranchiata.		
Inoceramus latus, *Mant.*(=orbicularis, *Münst.*)	I	
Lima globosa, *Sow.*	I	
Neithea quinquecostata, *Sow.*	I	
Ostrea vesicularis, *Lam.*	I	W
Pecten elongatus? *Lam.*	I	
——— orbicularis, *Sow.*	I	W
Plicatula inflata, *Sow.*	I	
Teredo amphisbæna, *Goldf.*	I	
Gasteropoda.		
Fusus, sp.	I	
Pleurotomaria, sp.	I	
Turboidea nodosa? *Seeley*	I	

—	Totternhoe Stone.	Grey Chalk.
Cephalopoda.		
Ammonites Ansteni, *Sharpe*	—	I. W
——— rothomagensis, *D'Orb.*	I	I
——— varians, *Sow.*	I	
Baculites, sp.	I	
Belemnitella plena, *Blainv.*	—	W
Nautilus deslongchampsianus, *D'Orb.*	I	
——— elegans, *Sow.*	I	
Turrilites costatus? *Lam.*	I	
Pisces.		
Cimolichthys lewesiensis, *Ag.*	I	
Lamna (Otodus) appendiculata, *Ag.*	I	
Oxyrhina Mantelli, *Ag.*	I	

The only fossils noted from the Chalk Marl are Ostrea vesicularis (from Burwell), Ammonites varians, and Turrilites costatus.

Middle Chalk.

General Description.

The district treated of in this memoir being contiguous to that described in the "Geology of the Neighbourhood of Cambridge," the zonal succession of the Middle and Upper Chalk is doubtless the same as in that area. This district had, however, been surveyed before that memoir was published, and before the importance of the Melbourn Rock and, to some extent, of the Chalk Rock as divisional lines had been recognised. The general course of the Melbourn Rock has since been traced through Suffolk and Norfolk,* but that of the Chalk Rock or of the zone into which it expands is not yet known.

The following table shows the succession which may be expected to exist in the eastern portion of Sheet 51 :—

Upper Chalk.	Chalk with flints and *Micrasters*	? 200 Feet.
	Nodular rocky beds (Chalk Rock)	20 ,,
Middle Chalk.	Zone of *Holaster planus*	50 ,,
	Zone of *Terebratulina gracilis*	100 ,,
	Zone of *Rhynchonella Cuvieri*	40 ,,
	Melbourn Rock	8 ,,

The *Melbourn Rock*, which forms the basement-bed of the Middle Chalk, is always conspicuous in those quarries where its base is exposed, because it rests directly on a soft buff marl (zone of *Belemnitella plena*), and as this crumbles on exposure to the weather, the hard rock above forms a projecting and overhanging cornice.

The lower part of the rock is a hard nodular mass 3 or 4 feet thick, consisting of compact white chalk in irregular lumps or

* By Messrs. W. Hill, Jukes-Browne, and Whitaker, see *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 546, 563–571. (1887.)

nodules which are embedded in a softer greenish-grey material, the whole forming a bed, or two massive beds, often much jointed. The upper part splits into thinner beds, the nodules occurring principally in layers from 6 to 18 inches apart, the chalk between these layers being compact and yellowish, with only a few small scattered nodules. There are occasionally partings of marl between the rocky beds, and these also contain nodules, on some of which young oysters may be found.*

The Melbourn Rock passes upward into chalk which is hard, yellowish, and rocky, but less nodular than that below, and very full of fragments of *Inoceramus;* it is also more fossiliferous, *Rhynchonella Cuvieri* and *Inoceramus mytiloides* occurring in abundance. Higher up the rock becomes whiter, smoother and softer, the nodules disappearing about 20 feet above the rock. The topmost beds of this zone are massive, tough and creamy white, sometimes rather hard, as on the Gog Magog Hills. The first flints come in about 40 or 50 feet above the base of the rock, but are only scattered single flints, generally with very thin rinds or white skins, and always showing distinct traces of sponge-structure.

The succeeding chalk (*Zone of Terebratulina gracilis*) is soft and white, in thick beds, with layers of soft grey marl at intervals. Flints are sometimes very numerous, and occur in layers of long finger-shaped nodules; but other parts of the zone are nearly destitute of flints. *Echinoconus subrotundus* is common in the lower part, *Terebratulina gracilis* and *Inoceramus Brongniarti* throughout the zone. The chalk itself is a nearly pure foraminiferal earth, microscopical examination showing that it consists of a fine calcareous powder embedding Foraminifera of several kinds, entire and broken, the most abundant being *Globigerina.*

[Of the Chalk Rock, the peculiar hard bed that divides the Middle from the Upper Chalk, no section has been seen in the district, and but one section hence northward through Norfolk. —W. W.]

Melbourn Rock and Zone of Rhynchonella Cuvieri.

The outcrop of the Melbourn Rock has not yet been traced through the district, but its general course is known. It enters to the north-west of Newmarket, and passes to the south of the spring-head at Exning. The importance of this horizon was not known when this district was surveyed, and if any pits exist in it no notes were taken of the sections exposed.

When the Bury and Soham Railway was being made, in 1879, Mr. Whitaker recognised the Melbourn Rock and the underlying bands of shaly marl (zone of *Belemnitella plena*), in the cutting south-west of Snailwell, and his notes on this have been given on p. 39.

The springs at Snailwell, and in Chippenham Park, are probably thrown out in the Melbourn Rock, but this is merely a surmise.

* For a fuller and general description, see *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 218, 230. (1886.)

North of the Kennett the country is covered with blown sand, but near Worlington Heath Farm there is a shallow pit which exposes the upper bed of the Melbourn Rock and some of the overlying nodular and shelly chalk; the section seen by myself and Mr. W. Hill in 1886* was as follows:—

	Feet.
Gravelly soil and rubble - - - -	4
Hard nodular whitish rock in thin beds, full of *Inoceramus mytiloides* and *Rhynchonella Cuvieri* -	4
Thin seam of greenish-grey marl.	
Hard nodular rocky chalk, white, with greenish marl between the lumps (no fossils) - - -	3
Talus hiding rock - -	4

The beds appear to have a slight dip east. The chalk terrace in which this pit is dug can be traced northward toward Worlington, and seems to emerge suddenly from beneath the great spread of gravel which covers the country between Freckenham and Worlington. It is very probable, indeed, that this gravel is banked up against the ridge formed by the outcrop of the Melbourn Rock.

The rock is seen again in the cutting on the railway to Mildenhall, just south of Worlington House, and it appears to have been quarried formerly by the side of the main road north-east of that house. On the northern side of the Lark we could find no trace of its actual outcrop, but the town of Mildenhall stands on the hard shelly yellowish chalk of the *Rhynchonella Cuvieri* zone; chalk of this description and containing that fossil, together with *Echinoconus subrotundus* and *Inoceramus mytiloides*, being exposed in a small pit at the eastern end of the town. The Melbourn Rock cannot therefore be far below the level of this pit.

All the quarries on the slope which borders the eastern side of Eriswell Fen are above the horizon of the rock, and it seems probable that the outcrop of the rock itself occurs near or a little below the level of the Fen, a position which it appears to hold as far as Lakenheath.

An old pit by the side of the road five furlongs south-east of Eriswell church shows shelly chalk with many fragments of *Inoceramus mytiloides*. About a mile to the north of Eriswell there is a small pit in hard chalk containing the same shell and *Rhynchonella Cuvieri*. This is at a low level and probably not far above the rock.

Between this and Lakenheath the country is deeply covered with blown sand. At Lakenheath, north-east of the church, there is a large quarry exposing about 30 feet of hard lumpy or nodular chalk that evidently belongs to this zone. The rock breaks principally along the joint-planes, and the weathered faces have a rubbly appearance, with large lumps of harder chalk standing out here and there, but not forming any definite or continuous bed. Fossils were unusually rare, *Echinoconus subrotundus* being the only one that was at all common. At the lowest level, near the entrance, harder and more regularly bedded rock is exposed, nodular and full of *Inoceramus mytiloides*, like that which always overlies the Melbourn Rock. Water comes in, according to the workmen, a few feet below the floor of this pit.

Fossils.

L. = Lakenheath. M. = Mildenhall. W. = Worlington.

Echinoconus subrotundus, *Mant.*, L. M.
Rhynchonella Cuvieri, *D'Orb.*, L. M. W.
Terebratula semiglobosa, *Sow.*, L. M. W.
Inoceramus mytiloides, *Mant.*, L. M. W.
Ammonites peramplus, *Mant.*, L. ?

A. J. J-B.

* See *Quart. Journ. Geol. Soc.*, vol. xliii., p. 564. The remainder of the account of this zone is also taken from this paper.

Upper Chalk.

As the older Tertiary beds do not come on above the Chalk for many miles eastward of our district, we may infer that the higher part of the Upper Chalk is not present, but has been eroded away. How much, however, of this division is present we do not know, its base not having been traced, from the absence of sections of the Chalk Rock, and from the eastern part of the tract being much hidden by Drift.

The Upper Chalk is marked lithologically by the general occurrence of layers of flint-nodules, and sometimes of continuous beds of flint; but in parts flints are comparatively rare.

North of the Lark the Chalk has been worked in various places for the sake of the flints, which were used for the making of gun-flints, an industry that still lingers at Brandon, just across our northern boundary. The following account of these pits is taken from a Memoir by Mr. Skertchly,* with some small additions and corrections from his note-book. Various local names are used.

The following information about Icklingham was given by Mr. Ashley, who worked the pits for flints there.

The stone used at Icklingham was dug on Icklingham Heath, close to the Seven Trees, 1½ miles north of the village. The place is called Seven Trees Brek;† the first part of the term applies to a clump of elms, of which five only remain, and the latter is synonymous with *Field*, an open space. The pits were very numerous, perhaps 500 in number, but their area is circumscribed. None were open at the time of my visit, and the only noticeable feature was the close proximity of the shafts, which averaged about 9 yards from one to another. The section at this place was, in 1876:—

	Ft.	*In.*
Sand - - - 1 *ft.* 6 *in. to*	3	0
Dead lime - - - - -	6	0
Soft white Chalk - - - - -	3	0
Toppings Flint - - - 5 *in. to*	1	0
Soft Chalk - - - - -	3	0
First Pipe-clay - - - - - 1 *in. to*	4	0
Hard Chalk, in large blocks, rings and smokes under the strokes of the pick - - - -	2	0
Upper Crust Flints, large, scattered, mostly grey 6 *in. to*	1	6
Soft white Chalk - - - -	3	0
Second Pipe-clay - - - - -	0	1½
White Chalk, rather hard - - - -	3	0
Wall Stone - - - - 1 *ft. to*	1	6
Soft Chalk, full of horns - - -	3	0
Hard Chalk - - - - - 3 *ft. to*	5	0
Third Pipe-clay - - - - -	0	1
Hard Chalk - - - - 1 *ft.* 6 *in. to*	2	0
Floor-stone - - - - 3 *in. to*	1	0
Moderately hard Chalk - - - - 2 *ft. to*	3	0
Very hard Chalk - - - - - 8 *ft. to*	9	0
Rough and smooth black Flint, a regular layer, in this differing from the stone at Lingheath. Only occasionally worked, and burrowed from above like wall-stone - - - - - 3 *in. to*	1	0
Mean about	45	0

* Memoirs of the Geological Survey. England and Wales. On the Manufacture of Gun-flints, the Methods of Excavating for Flint, the Age of Palæolithic Man, and the Connexion between Neolithic Art and the Gun-flint Trade, pp. 10–14. (1879.)

† Mr. Bennett says that Brek is a name given to the large fields.

The similarity of this section with those at Lingheath and Broomhill, from which it is distant 8 and 10 miles respectively, is very striking.

A remarkable pit was sunk about 300 yards west of the above, in which the first three "stones" were missing. The section was as follows, according to Mr. Ashley:—

	Ft.	In.
Sand	3	0
Dead lime	6	0
Soft white Chalk	7	0
First Pipe-clay	0	3
Soft white Chalk	6	0
Second Pipe-clay	0	1
Soft white Chalk	*about* 12	0
Third Pipe-clay	0	1
Hard Chalk	2	0
Gulls (Paramoudra), nearly 3 ft. in height, grey and grisly, and of no use for gun-flints, in three tiers with 3 in. partings of chalk between	9	0
Floor-stone in a regular sase [local name for layer].		

The thicknesses of the chalk beds in the above section must be much overstated, for Mr. Ashley told me the pit was 25 ft. deep, whereas his account makes it 40. It is certain, however, that the pipe-clays were found as stated, and the local absence of the toppings, upper-crusts, and wall-stone, and the presence of gulls above the floor-stone are very singular.

The stone obtained from Seven Trees Brek is very good, and of much better average quality than that found near Brandon. It is generally intensely black, often jackdaw-coloured, of good running quality, and the coats are hard. To save expense of cartage Ashley often quartered and flaked his stone on the spot, and the numerous cores lying about show how profligate he was of his wealth of stone, for very many of them would be gladly flaked over again by the Brandon men.

Good stone is obtained from a chalk pit close to the lodge of Elvedon Park. The section was as follows in 1875:—

	Feet.
Sand (? wash)	0 *to* 3
White Chalk, with scattered horns flints	11
Pipe-clay (marl)	$\frac{1}{3}$
[In note-book, White Chalk, 3 ft., is inserted here.]	
Upper Crust Flints, large and irregular	$\frac{2}{3}$
White Chalk	$4\frac{1}{2}$
Wall stone (flints)	1
White Chalk	4

The upper crusts here yield the good flint. This is unusual, but sometimes occurs at Lingheath; the stone is known as "best upper-crust." The chalk lies regularly, and its beds average about a foot in thickness. The layer of pipe-clay shows a north-easterly dip of 1°. A specimen of *Anarchytes ovatus* was found here.

At Shaker's Lodge, on Wangford Rabbit Warren, about 2½ miles south of Lingheath, on the summit of the hill, floor-stone was met with in sinking a well, and a trial-pit was opened; the bed, however, has not been worked. The section was still open in 1875, and showed:—

	Feet.	
Sand, full of angular flints	1 *to* 3	$7\frac{1}{3}$
Dead lime	1 *to* 3	
Hard Chalk	3 *to* 1	
Floor-stone	$\frac{1}{3}$	

This section affords a means of calculating the dip of the beds. The surface of the ground is 163 feet above Ordnance Datum, the floor-stone 158 feet. The surface at the Poor's Plantation, Lingheath, is about 50 feet above datum, the floor-stone 15 feet. The distance being $2\frac{1}{2}$ miles gives as the dip 143 feet in that distance, or 57·2 feet a mile, equal to 1 in 93 or about half a degree.

Old flint-pits are seen in and around Elms Plantation, in Brandon Park, about a mile due north of Shaker's Lodge, but I have not been able to obtain any account of the section. They were worked out before the Lingheath pits were started, and may perhaps have been dug before the gun-flint trade arose.

Mr. C. B. Rose has remarked that "at Thetford, cylindrical forms of flint from 18 to 24 inches in length are numerously distributed through the chalk; they are very sonorous, clinking loudly when struck against each other . . Exceedingly thin seams of flint are seen" also.*

The following notes, referring to the south-eastern corner of the district, are from Mr. J. H. Blake:—

"At a large chalk-pit on the western side of the road, a little more than half a mile S.W. by S. of Fornham All Saints Church, about 20 feet of chalk was exposed, containing flints irregularly interspersed. About 12 feet above the bottom of the pit, two tabular bands of flint, each from $\frac{1}{2}$ to 1 inch thick, 6 inches apart and parallel, occurred in horizontal but slightly undulating planes, extending across the whole of the section. A little brown loamy clay overlaid the chalk."

"Chalk is exposed in places in the neighbourhood of Fornham St. Martin Church, and also in the railway-cutting three eighths of a mile E.S.E."

Other sections of Chalk will be noticed under Drift.

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* *Proc. Geol. Assoc.*, vol. i., no. 8, p. 231. (1862.)

CHAPTER V. GLACIAL DRIFT.

On leaving the Chalk we come to a great gap in the geological series, for in this district not only are the highest beds of the Chalk absent, but also the whole of the older Tertiary beds, and, moreover, no trace of the newer Tertiary beds (of Crag age) has yet been found, nor is such trace likely to occur. We find the Chalk, as well as the underlying formations, irregularly covered by the Glacial Drift.

This Drift here consists chiefly of a great sheet and of isolated masses, of various sizes, of Boulder Clay; but beneath this clay there is in places gravel or sand, and less often loam; these underlying beds being sometimes associated with a lower and thinner bed of Boulder Clay: again above the clay there are here and there patches of gravel, which are more easily classified with the Glacial Drift than otherwise.

For the loam or brick-earth beneath the Boulder Clay Mr. Skertchly proposed the name Brandon Beds;* but as this loam is endowed with older names, being probably the equivalent of part of the Lower Glacial, or of the Contorted Drift of MR. S. V. WOOD, as it does not occur at Brandon itself (though there are patches in the surrounding country), and as it is better developed in various other neighbourhoods, the name is hardly needed. Indeed it seems a questionable thing to give names to divisions of the Glacial Drift, other than such lithological ones as are needful, and the term Glacial Loam is quite enough, for present purposes at all events.

BEDS BELOW THE BOULDER CLAY.

Although on the map loam has been shown distinct from gravel or sand, yet as the outcrops of these lower beds are small, when compared with the tract covered by Boulder Clay, and as, moreover, they occur somewhat irregularly, it will be convenient here to group the whole. Practically the distinction between loam and gravel is important, but geologically, in this case, it is not so, as all these beds are closely allied, and of no great thickness.

South of the Lark.

In the western part of our district there are no beds which we can with certainty assign to this part of the Drift; but possibly the small patch shown on the map more than a mile S.S.E. from Barraway may be so classed provisionally.

Of this MR. SKERTCHLY noted, in 1874, that "there is sandy gravel at the northern end of Padney highland. The sand is like that of the Lower

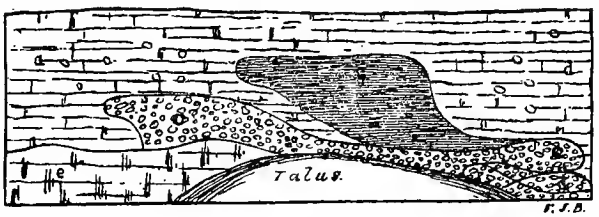
* Gun Flint Memoir, and *Rep. Brit. Assoc.* for 1879, *Sections*, p. 379.

Greensand, with small angular flints, not bedded: it was seen to a depth of four feet, beneath a foot of moory soil."

Mr. Bennett notes the section shown in Fig. 3, as occurring "in a pit by the road half a mile south of Barton Mill," where, however, the lower beds do not come to the surface :—

Fig. 3. *Section in a Pit south of Barton Mill.*

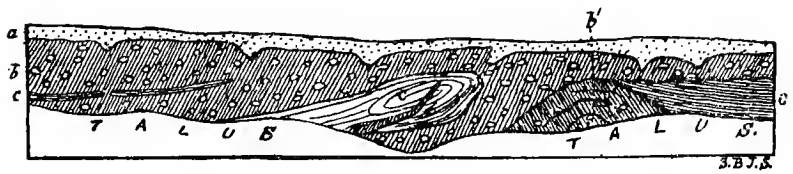
Scale about 8 feet to an inch.



Drift { *a*. Reconstructed chalk, with pebbles of quartzite [*r* part of Boulder Clay].
b. Fine buff laminated loam, passing into *a*.
c. Pebbly gravel, mostly of chalk, but with quartz and quartzite.
d. Fine false-bedded sand.

e. Chalk.

Fig. 4. *Section in a Pit south of Tuddenham.*



a. Sand and gravel.

Glacial Drift { *b* & *b*^{1}. Boulder Clay.
c. Loam.

Vertical and Horizontal Scale the same. Height 30 feet (? less.—W. W.).

Mr. Skertchly has left the following note of a pit near Tuddenham. "Near the road about 1½ miles south of the village was a section showing how Boulder Clay has worked up the loam, contorting it, dragging it from its original position, and so influencing it that in places it is difficult to know whether to call the material 'Boulder Clay made up of loam,' or 'loam mixed up with Boulder Clay.' On the right (east) of the section (Fig. 4) the Boulder Clay has squeezed under and tilted up a mass of the loam. In the centre the loam is not only tilted up but bent over, and a tongue of the Boulder Clay (a few inches thick and several feet long) is injected in to the loam. At *b*^{1} a mass of Boulder Clay lies distinct from the rest, as if it had been squeezed into that above."

When I saw this old pit not much could be made out of it: one could see little but a confused jumble of loam and Boulder Clay; but Mr. Bennett had also noted patches of loam in the Boulder Clay, the latter in one case penetrating some way into one of the masses.

Mr. Bennett has recorded sections from Tuddenham to Hengrave, and the following descriptions are from his notes.

"In a stack-yard about half a mile south-east of Tuddenham Church the following beds were shown by a pit, to the depth of about six feet":—

Brown loam, sandy at top, bedded with bands of grey and puce; from a foot to 6 feet or more, resting irregularly on the next and at one part going down below the bottom of the pit. On one side of the pipe thus formed there is a lining of gravel and buff sand, with a carbonaceous band; at the lower part of the other side a few land-shells (?) were found.

Buff and grey loam, with a little chalk.

"The upper bed may be merely the top weathered part of the lower one."

"There is a patch of loam at Lackford Green, but nothing was seen to show its age."

"A pit a quarter of a mile S.W. of Lackford Church gave the following section":—

Drift { Brown Boulder Clay, with much chalk and some red chalk, and with a lenticular mass of chalk-rubble, up to a foot thick; 2 feet.
Sandy gravel; 4 inches.
Reconstructed chalk; 2 feet.

Chalk; 4 feet.

"The patch of gravel mapped here, and that to the east, seem by position, to crop out from beneath the Boulder Clay, as these occur in small valleys, cut out of the Boulder Clay; but there is no direct evidence. Near the southern end of the western outcrop sand was seen, and in the other end the gravel and sand seemed to rest on the Chalk; the gravel is largely made up of quartzite pebbles."

"At a brick-kiln a mile south of Lackford Church there was at the top some 5 feet of Boulder Clay, with sand-galls, large unworn flints, and lenticular patches of clean clay, beneath which came brown sandy loam, said to be 9 feet thick and to be underlain by Chalk."

"About a quarter of a mile south-westward of Flempton Church a pit, marked on the map, showed rather fine subangular gravel resting on Chalk and surrounded by Boulder Clay. The section was not clear, but the gravel, which is on high ground, seems to rise as a boss from beneath the clay."

In the larger outcrop westward of Hengrave "there was a kiln, a mile south of Flempton Church, but no good section was seen. Most of the earth is got from the Boulder Clay, which is washed and seems to contain some loam. At the edge of the wood brown clay, over 2 feet thick, was seen overlying rather coarse white sand, reddish at the base, to 4 feet. The well continues the section to the Chalk (*see* p. 114). Westward of Stanchels Farm Chalk has been dug; but in this valley no pits were seen in the gravel, which has been mapped as Glacial from its position with regard to the surrounding Boulder Clay."

The following is from Mr. J. H. Blake's notes:—"In a pit three eighths of a mile W.S.W. of Fornham All Saints Church layers or masses of coarse gravel and fine buff sand with small pebbles were seen, at the eastern side, in a nearly vertical position and abutting against Boulder Clay; and other parts of the pit gave evidence of considerable disturbance subsequent to the deposition of all these beds. Many boulders of Lias shale and many coprolites, Belemnites, Grypheas, and other fossils were seen in the gravel."

"In another pit, in a large field about five eighths of a mile south of the church, there was Boulder Clay at top, about 7 feet down in which a layer of coarse consolidated reddish-brown sand, with many shell-fragments, was seen. Underlying, and in some places tonguing into, the clay was a thickness of 6 feet of fine buff and sometimes false-bedded sand, and gravel, in layers and lenticular patches. Many angular and rounded boulders, up to 1½ feet in length and of various rocks, occurred in the

gravel as well as in the clay, together with quartz pebbles and angular flints, as well as various derived fossils."

Between the Lark and the Little Ouse.

To continue with MR. BLAKE's notes:—"A pit in the southern part of the wood at St. John's Hill, and little more than half a mile S.S.E. of Fornham St. Genevieve Church, showed a thickness of about 4 feet of flint-gravel over sand, mostly buff, but reddish in places, and here and there with a few small flints, of which about 7 feet was seen."

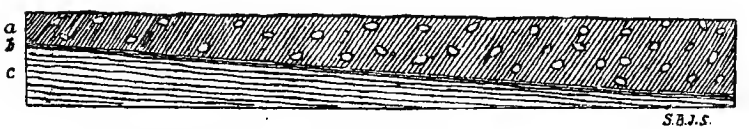
MR. BENNETT notes that "a small pit about a mile a little S. of E. from Timworth Church showed Boulder Clay over buff sand. The gravel of Ampton Park and of Livermere Park is mapped as Glacial from its position, though there is no section showing the superposition of the Boulder Clay."

The following account of the section at the brickyard about three quarters of a mile N.W. of Culford Hall is by MR. SKERTCHLY:—

FIG. 5.

Part of the Section at Culford Brickyard.

Vertical and Horizontal Scales the same.



a. Boulder Clay. *b*. Hardened loam. *c*. Buff loam.

"A very clean section has been opened, showing the following succession":—

		FEET.
Sand and gravel		0 to 9
Glacial Drift	Boulder Clay	0 to 12
	Buff laminated loam	15
	Harder loam, with seams of sand and carbonaceous markings	15
	Cemented gravel, thin.	
Chalk.		

"The loams which dip south-west at a slight angle have been planed off by the Boulder Clay and in places are finely contorted. At first sight it would seem that the clay rested evenly on the loam; but close inspection shows the above-mentioned points, and gives proof of the influence of pressure, for the top part of the loam has been converted into a hard mass, the laminæ of which are parallel to the Boulder Clay above and not to the loam beneath."

"The base of the Boulder Clay varies in character with the underlying loam: where the latter is more sandy, so also is the former."

In a later note MR. SKERTCHLY says:—"I have since found freshwater-shells, fragments of wood, and a worked flake here."

The REV. O. FISHER has shown me a cast of the flake in question (I believe that I have seen the original also), and there can be no doubt as to its genuine character: it is said to have come from the brickearth. He also tells me that at a later date (about 1884) "the Boulder Clay at the eastern face of the pit was nearly worked away and had degenerated into a sandy gravel; but on the southern side there was a fine exposure of it."*

* See FISHER, *Proc. Camb. Phil. Soc.*, vol. iii., p. 285, and HUGHES, *Journ. Anthrop. Inst.*, vol. vii., p. 162.

When I saw the section there was a hollow of sand between the Boulder Clay and the loam, on the southern side.

Returning to Mr. Bennett's notes, "a small old pit half a mile north of West Stow Church showed the following succession":—

Brown stony Boulder Clay, with chalk pebbles. At one part all the chalk has been dissolved out, and there are sand-galls: the division between this and the chalky clay was sharply marked and nearly vertical; 6½ feet.
Thin layer of chocolate-coloured clean clay.
Pinkish-brown clayey sand, weathering greenish, and having a marked even junction with the clay above; 1½ feet.
Finely laminated brown sandy loam; 6 inches.

In the isolated patch of loam "about three quarters of a mile N.N.W. of West Stow Church, an old pit in a field, showed a capping of stiff reddish clay with a few flints, which may be weathered Boulder Clay, over very finely laminated buff loam." Our former colleague, Mr. A. Colvin, found the impression of a small leaf in the loam here, on a visit with other geologists.

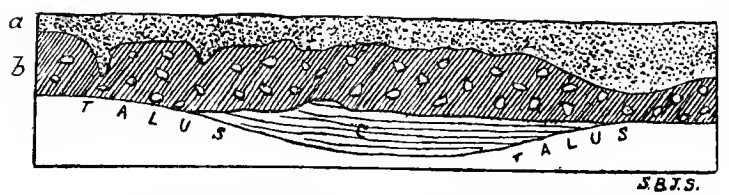
"From south of Wordwell there is gravel up the valley eastward for more than 2 miles, with an outcrop of chalk in the valley-bottom for some way. At the southern side of Limekiln Plantation, S.E. of Wordwell, a large pit showed a thickness of 18 feet of pebbly gravel, obscurely bedded, with a little sand in places, and at one place a thin layer of loam: many of the flint pebbles are large; but hard chalk pebbles, some of considerable size, form quite half of the material, and there is a fair quantity of red chalk pebbles. About a mile to the east, at the end of a cart-road, was another pit in coarse flint-gravel."

"At the head of this outcrop, on the eastern side of the high road near the 5 mile-stone, is a large pit, about 25 feet deep, which showed alternating gravel and sand, capped at one place by a patch of Boulder Clay."

To Mr. Skertchly we owe the accompanying figure of a section near Livermere Heath Farm. He notes that "in most places the Boulder Clay rests pretty evenly on the loam. Here and there, however, the former has worked into the latter, and, on the northern side, a tongue of the clay intruded into the loam."

Fig. 6.

Section in a Pit near Livermere Heath Farm, north of Ampton.



Vertical and Horizontal Scales the same. Depth 16 feet.

a. Sand.
Glacial { *b*. Boulder Clay.
Drift { *c*. Loam, dirty, with flints and pieces of chalk.

A note by Mr. Bennett of a pit about a quarter of a mile N.E. of the farm may refer to the same section. He adds quartzite pebbles and included pieces of Boulder Clay to the contents of the loam, and describes

it as rising up to the surface, though over too small an area to be mappable.

MR. BENNETT continues:—On the western side of the high road, at the northern end of the gravel-patch, N.W. of the farm, "a pit gave the following section, to a total depth of about 8 feet":—

Gravel, resting very irregularly on the next; from 10 to 2½ feet.
Fine gravel, of flints in a chalky matrix, resting very irregularly on, but passing down into, the next; up to 5 feet.
Reconstructed chalk, with unworn flints; 1½ to 5 feet.
Chalk seems to be touched at the base.

From Wordwell along the edge of the great sheet of Boulder Clay, westward to above the Icklinghams, and then northward to near Downham High Lodge, no outcrop of beds between the Chalk and the Boulder Clay has been seen, and only one note of a section in such has been made. This section is near our northern boundary, and MR. SKERTCHLY thus describes it.

"'A pit in May Day Plantation, by the eastern end of Brandon Park, gave a peculiar section, to a depth of about 16 feet, but unfortunately much hidden, in 1875. This seemed to show that the red sandy beds are of Glacial age, for light yellow Boulder Clay, full of striated pieces of chalk, was seen to overlie them here and there. At one part the gravelly sand was cemented, by carbonate of lime, into a conglomerate. Pinkish brickearth, with a tendency to lamination, was seen at one spot, overlain by Boulder Clay. Quartzite pebbles and small boulders occur sparingly in the Boulder Clay, but chalk is very abundant: blocks of septaria and of clay-ironstone lie about, and two large boulders of Neocomian sandstone, one with black phosphatic nodules." From a rough diagram of the 'apparent section' in MR. SKERTCHLY's note-book, it would seem that a little brickearth may occur above a little Boulder Clay, beneath which there is again brickearth, underlain by more Boulder Clay, thinning out sometimes, so that the sand and gravel at the bottom then underlies the brickearth. From this one may infer that we have here local beds, beneath the great sheet of Boulder Clay; but it does not follow that other patches of sand and gravel, which occur only above Boulder Clay, in the neighbourhood are also of Glacial age.

From the northern edge of the district, at Downham High Lodge, south-eastward to Thetford Heath, and then round by Elvedon and Calthorpe Heath, to Barnham St. Gregory, at the eastern edge, there are in places signs of beds of Glacial Drift below the Boulder Clay, though the outcrops are few and small.

Speaking of the loam generally, MR. SKERTCHLY says—"I have noticed that in places, as near Elvedon, where the loam is sandy and has Boulder Clay beneath, it seems little affected, whereas, where the loam is clayey, as at Thetford, it is much crumpled by the Boulder Clay beneath, as in other places, where it is overlain by Boulder Clay."

"It would seem as if the tenacity of the clay enabled it to receive and retain contortion more readily than is the case with sand. Moreover, clay yields more to pressure than sand does."

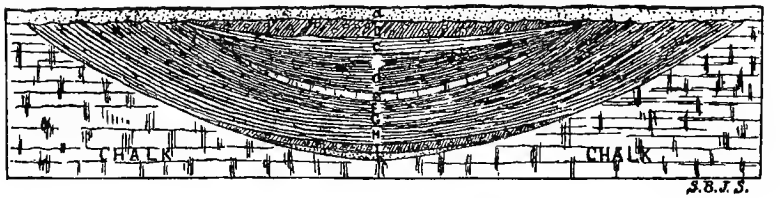
This is on the supposition that the Boulder Clay beneath the loam has been intruded, and was not pre-existent; but this may be doubted, as a rule at all events.

The accompanying figure and description of the interesting section on the southern side of the road at Elvedon Gap* are by Mr. Skertchly, who saw the pit in good order.

Fig. 7.

Section at Elvedon Gap Brickyard.

(Taken through the centre of the pit.)



		Feet.
a. Sand and gravel		3
Glacial Drift.	*b*. Dark blue, tough boulder clay, full of scratched stones	6
	c. Grey clay	4
	d. Blue clay	12
	e. Rock. Consolidated loam, coherent enough to form a roof, beneath which the loam is tunnelled for a short distance	0 to 2
	f. Buff laminated loam	4
	g. Loam (as above) and gravel	4
	h. Loam (as above)	4
	i. Chalky clay, not seen, but described as like the top bed of Boulder Clay	2
	j. Gravel, not seen (reached by boring)	2

"The section, Fig. 7, shows the appearance of the pit, all the details being occasionally visible at once. The beds lie in a pot-hole, which has most likely been formed by the gradual solution of the chalk beneath. It is clear that the beds have not lost their relative positions, and the effect of the gradual sinking is shown by the occurrence of many tiny faults in the loam."

"A well, 20 yards from the pit, passes through 2 feet of sand into the Chalk."

At a later date the general section (as far as could be seen) seemed to be Boulder Clay over laminated loam &c., over sand, the beds being troughed, as shown above.

At the northern end of the patch of loam a pit showed, at a later date, buff sandy laminated loam, resting in a hollow in light-coloured Boulder Clay.

Mr. Skertchly says that "near Elvedon buff loams and fine sands crop out beneath the Boulder Clay, 6 feet of which are also seen below."

Mr. Bennett notes that about a mile south-westward of Elvedon, "by the 75th mile-stone, on the high road, a pit showed 20 feet of buff laminated sandy loam, capped by sand and resting in a hollow of Boulder Clay."

It would seem, therefore, as if some of these beds are beneath the great sheet of Boulder Clay, but are accompanied by another bed of like clay.

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* On the old Ordnance Map there are two places of this name, and both on the same road! One is 1½ miles N.E. of the village, and the other 2½ miles S.W. of the same. The former is here meant.

Mr. Bennett also notes "a large pit nearly half a mile S.E. of Barnham St. Gregory Church, showing brown sandy loam, with a black layer, which seems to rest on and pass into stiff brown and grey clay, beneath which, in the middle of the section, is brown bedded sand, with ferruginous bands, getting clayey at the bottom, rising in a boss. A clean cut at the western end showed dark slate-coloured clay, almost black at the lowest part, and with land-shells: bones also are said to have been found. Boulder Clay surrounds the brickearth (of which a thickness of about 20 feet was seen), but no junction-section occurred; so that it is doubtful whether the latter is above or below the former:"

Of the patch westward of Barnham, Mr. Skertchly has left the following note:—

"In 1876, the pit westward of North Farm, Barnham St. Gregory, was open to the depth of 20 feet, and gave the following section":—

Sandy gravel, a mere wash, cutting into the bed below.
Fine laminated buff loam, apparently composed of clay chalk and sand, lying in a long sweeping curve. Here and there a small black flint and a few bits of race.

"About five chains further west another pit showed the loam, overlain by Boulder Clay, into which it seems to pass in places. The thickness of the clay did not exceed 3 feet."

There are also some isolated gravelly patches on the Chalk here. One, of sand and gravel, is less than a mile S.E. of Elvedon. Another stretches northward from the high road at the 78th mile-stone, S.W. of Thetford, and its northern end is suggestive of an esker, a name applied to certain long mounds of gravel, &c. of which further evidence was got during the progress of the Geological Survey in Norfolk. A pit on the eastern side of the plantation here, and about a quarter of a mile from the road, showed a hollow of sandy earth in gravel, which latter was mostly coarse and partly chalky. In the south-western corner of another pit, near the road, the chalk came to the surface at one part, being capped by a little coarse gravel on the one side and cut into by bedded sandy chalky gravel on the other.

Away from the mass of the Boulder Clay a small patch of loam occurs beneath Boulder Clay near Mildenhall, and is of especial interest from Mr. Skertchly having recorded the finding of worked flints therein. He remarks, "I have got no implements, but have taken several flakes, from the loam. Mr. S. G. Fenton, formerly of Mildenhall, obtained a goodly number of rudely fashioned tools, and favoured me with drawings of about a dozen." At a later date Mr. Skertchly got a small implement, said to have come from the loam. He describes the section as follows:—

"At the Mildenhall brickyard, N.E. of the town, the pits, as is often the case, are dry in winter and filled up in summer; so that it is only by watching the work at various times that the true relations of the beds can be made out. The accompanying figure (8) shows the restored section, which I have seen in its entirety. At present [this was written about 1877] the exposnre is not good, but Boulder Clay can be seen lying on the brick-clay. Several of my colleagues have seen the section and consider it to be quite satisfactory."* On a visit with Mr. Skertchly, I saw an unmistakeable mass of Boulder Clay resting in a hollow of the brick-clay; but on a later visit this had disappeared, showing how such sections may vary from time to time.

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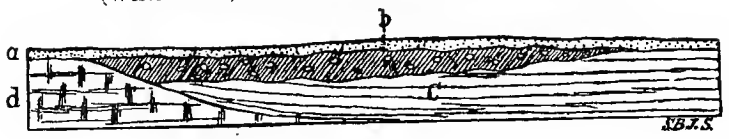
* See H. B. Woodward, *Proc. Norwich Geol. Soc.*, pt. 1, p. 33. (1878); and *Proc. Geol. Assoc.*, vol. ix., no. 3, pp. 125, 126. (1885.)

FIG. 8.

Section at Mildenhall Brickyard.

(Western side.) Vertical and Horizontal Scales the same.



a. Sandy soil.
Glacial Drift { *b*. Boulder Clay.
c. Grey laminated loam.
d. Chalk.

"On the eastern side of the yard the following section was noted in 1875."

Bedded sand and gravel; 7 feet.
Light-bluish loam; 12 feet.
Chalk.

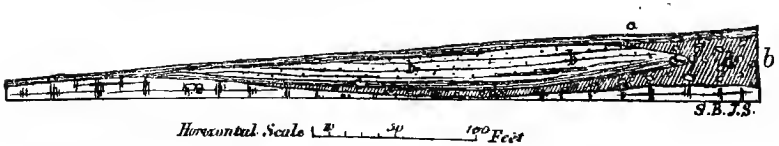
"To the westward another pit showed 10 feet of Boulder Clay, which was much indebted to the loam for its construction, and it is difficult to avoid the conclusion that the ice ploughed out most of the loam, leaving but a few isolated patches."

"In the well chalk was seen on one side, at about 9 feet deep, and sand on the other side, the junction being apparently almost vertical."

Of the Glacial age of the loam just described there can hardly be any doubt; but the age of that at the northern part of Warren Hill, nearly two miles E.N.E. of Mildenhall Church, is by no means so certain, and by taking its description here one must not be understood to assert its title to the term Glacial. Unfortunately it must be described somewhere, and whether here or later on, amongst the Post-Glacial deposits, must go against the feelings of one or other group of geologists; the principle, "first come first served" leads one to take the matter up at the earliest chance. The following account of the section is by MR. SKERTCHLY, who also remarks that "a very fine pointed oval flint implement was found, measuring $4 \times 2\frac{1}{2} \times \frac{3}{4}$ inches. It had weathered to a pale ochreous colour, but in places retained its original blackness, and it is by far the finest specimen that I obtained from these loams."

FIG. 9.

General Section at Warren Hill, east of Mildenhall.



a. Sand and sandy soil, which spreads over all, as usual in the district.
b. Boulder Clay.
c. { Fine sand and chalky gravel, up to 22 feet thick, gradually thinning away westward, towards the Boulder Clay. Yields flint implements and mammalian bones.
Brickearth, reddish-brown [rusted] above, blue below, seldom over 4 feet. Yields implements and mammalian bones (*Cervus*, *Elephas*).
d. Chalk.

"Warren Hill, about $1\frac{3}{4}$ miles eastward of Mildenhall, has been long known as a locality for flint implements, and has been described by

Prof. Prestwich, Dr. J. Evans and others.* These authors class the brickearth as Post-Glacial, because of its resting on Boulder Clay. I find however, that Boulder Clay rests on the implement-bearing beds, as well as underlies them, as shown in the restored section Fig. 8."

"The actual sections along this line were so close that at no place was there an interval of more than a few yards."

"At the point under where *a* is marked in the figure, a pit now open [? abont 1876] shows the following section, quite clear":—

Sand, 0 to 2 feet.
Boulder Clay, 4 feet.
Coarse chalky flint gravel, 6 feet.
Mottled red and blue clay, in which I found several worked flints, 5 feet.
Boulder Clay, seen to 2 feet.

"The late Mr. S. V. Wood, Jun., on seeing a section across Warren Hill, that I had drawn, suggested that the loams may really be newer than the Boulder Clay. He remarked that these beds, being of freshwater origin, may have been deposited by streams that flowed between banks of Boulder Clay, and undercut those banks. I do not doubt that such cases may occur, though I never saw a stream undercut its bank yards inwards."

North of the Little Ouse.

We have now to treat only of a very small tract north of Thetford, where, however, there are or have been, good sections. These have been recorded by Mr. Skertchly, and the following description is mostly by him, with some additions from Mr. Bennett's notes, and from my own. The introductory paragraph was clearly written on the supposition that the Boulder Clay seen is the same bed as the great mass to the south; but this seems by no means certain, and when seeing the pit south of the Waterworks I was inclined to regard the Boulder Clay there rather as one of those lower beds that sometimes occur in such a position.

"At Thetford the loam is not entirely buried in Glacial clay, and an explanation of the relation of the loam to the Boulder Clay, given on the spot by Mr. T. Belt, seems to meet the facts of the case better than any other; namely, that the ice, moving along the valley of the Little Ouse, pushed its moraine beneath the loam at this point, but did not succeed in lifting it right away. We must, of course, suppose that the loam was buried beneath the Boulder Clay and then exposed by denudation."

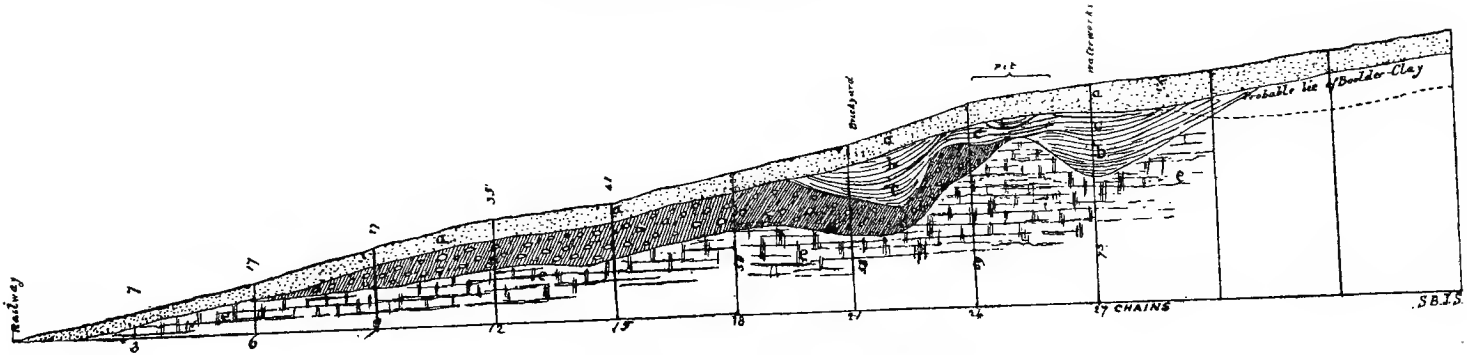
"A most instructive set of sections occurred around the Waterworks, which I was enabled to study under exceptionally favourable circumstances, during the progress of the works (in 1877 ?). From the Waterworks southward to the brickyard I saw a continuous section, given by the well and the excavations for cisterns, by the trenches in which the pipes were laid, by an old pit, and by the brickyard close by. Besides these I obtained details of all the pits and trial-holes that had been made by the brickmakers during the previous twenty years."

"The accompanying general section (fig. 10) has been made with great care from levels taken by the theodolite, and from the information noted above."

* *Phil. Trans.*, vol. cliv., p. 253. (1864); Ancient Stone Implements of Great Britain, pp. 488–492. (1872.)

FIG. 10.

General Section along the Road from Thetford Railway Station to the Waterworks (N.N.W.).



Heights, in feet, above the level of the rails.

a. Sand and gravel.
Glacial Drift { *b*. Blue clay. *c*. Buff loam. *d*. Boulder Clay.
e. Chalk.

"The sand and gravel lies irregularly on the beds beneath. The Boulder Clay underlies the loam for a distance of 5 chains only, and is missing at the Waterworks and at the eastern side of the brickyard to the south. I believe this Boulder Clay to be a tongue intruded beneath the loam, and this opinion is supported by the disturbance which the latter has undergone, from the clay beneath. The presence of Boulder Clay under the loam does not, therefore, prove that the loam is newer than that clay."

"The proof that Boulder Clay also overlies the loam was not patent; but I have satisfied myself that such is the case. Trial-holes have been made over a considerable area, for the purpose of finding the loam, and in every instance this, as well as the underlying Boulder Clay, was found to thin out, as the Boulder Clay thickened upon it higher up the hill."

There is no Boulder Clay on the hill-top, however, and no evidence that any occurs over the loam. In every section hereabouts the clay is beneath the loam. Of course if, as has been suggested above, the clay in question does not belong to the great sheet of Boulder Clay, but is a lower bed, it is possible, and indeed probable, that the clay of the great sheet is newer than the loam, and this conclusion led MR. BENNETT and myself, at a later time, to class the loam as Glacial, rather than as Post-Glacial. Some observers have preferred the latter classification, because of the occurrence of Boulder Clay beneath the loam; but the conclusion is by no means warranted: it is not enough to find *a* Boulder Clay beneath some other bed to justify one in calling the latter Post-Glacial; it is needful to find *the* Boulder Clay, that is clay which can be identified as belonging to the great sheet, for there are various beds of Boulder Clay.

The details of the Thetford sections are as follows:—

Brickyard nearly half a mile N.N.W. of the Railway Station.

Sand and gravel; up to 8 or 10 feet.

Glacial Drift. { Dark bluish-grey laminated clay; up to 12 feet or more.
Buff loam; said to be up to 16 feet.
Boulder Clay, to Chalk; 0 to 7 feet.

Pit on the other side of the high road, a little South of the Waterworks. The letters correspond with those of Fig. 11, from a sketch made at a later date by MR. BENNETT.

a. Sand and gravel; up to 7 feet.

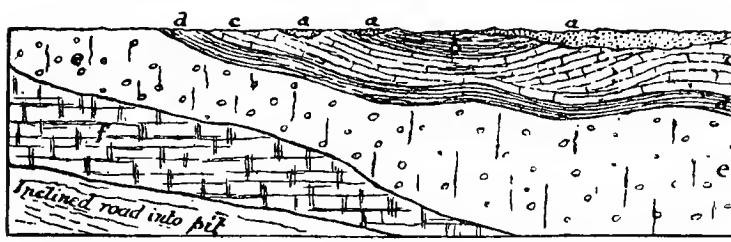
Glacial Drift. {
b. Buff laminated loam; up to 7 feet.
c. Bluish-grey clay, laminated toward the base, and seeming to pass into the next; 3 to 7 feet.
d. Buff laminated loam; a foot or more.
e. Light-coloured Boulder Clay, to Chalk; up to 10 feet.

f. Chalk [? regarded as a boulder by MR. SKERTCHLY], seen to 6 feet.

The Drift beds have an easterly inclination, cutting into the Chalk in that direction.

FIG. 11.

Section in a Pit south of Thetford Waterworks.



At the Waterworks : —

Sand and gravel; 10 feet.
Glacial Drift { Buff loam ; 6 to 7 feet.
Blue Clay, to Chalk ; 13 feet.

Old Pot Kiln, about half a mile N.E.

Sand and gravel; 6 feet.
Red clay, to Chalk; 10 to 20 feet.

Mr. Bennett gives the following note of a pit two thirds of a mile N.E. of the Railway Station :—

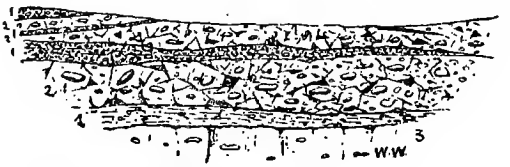
Glacial Drift { Gravel and sand; about 1½ feet.
Brown sandy laminated loam ; up to about 1½ feet.
Brown chalky Boulder Clay, showing inclined bedding, and containing a lenticular mass of reconstructed chalk (with Boulder Clay in its midst); 24 feet or more.

Chalk, at one part.

A smaller pit, dug below the bottom of the main one, gave a section showing alternating layers of broken up chalk and of Boulder Clay, as in Fig. 12, in 1881.—(W. W.)

Fig. 12.

Section in a Pit a mile N.N.E. of Thetford.



1. Buff sandy Boulder Clay.
2. Broken up chalk and flints.
3. Chalk and flints. ? in place, or more of 2.

This section is described here on the supposition that the Boulder Clay may be one of those lower beds that sometimes occur, rather than belonging to the great mass at a higher horizon.

CHAPTER VI. GLACIAL DRIFT.

Boulder Clay.

General Account.

We have now to notice that division of the Glacial Drift which most clearly owes its formation to ice. It is a bluish grey clay, which changes, by weathering, to a pale grey or to a yellowish brown; in some cases the weathering goes to the extent of the dissolving out of all the chalky matter, and then the characteristic feature of the deposit is lost. This clay is mostly crowded with stones of various sorts and sizes, by far the commonest being chalk and flints, so much so indeed as to give a marked chalky character to the whole bed. Many of the stones, notably the fragments and boulders of hard chalk, show signs of the action of ice, their surfaces being smoothed and scratched in the same fashion as are stones from beneath existing glaciers. The stones from other formations point mostly to a northern origin, and show that the ice must have had therefore a general southerly movement, whether it was land-ice, or water-borne ice, or partly one and partly the other, a question of a highly controversial kind.

Lest the name Boulder Clay may mislead, it may be well to note that the great majority of the stones are of no great size, ranging down to very small pebbles: large stones, however, are common; but actual boulders are less so, and none of very great size have been noted in our district, except for the great erratic of Roswell (Ely) and perhaps for certain large masses of chalk near Thetford, which Mr. Skertchly takes to be huge included boulders. There are sometimes also patches of loam in the clay.

In the western part of the district, that is in Ely and in the neighbouring islands, there are outlying patches of Boulder Clay, some of fair size. In the central part it is absent, except for some small patches, having been almost entirely eroded away. The vast amount of erosion that has taken place in Post-Glacial times over this tract, from the Fens for miles eastward, is apparent, as one cannot doubt that the Boulder Clay once stretched right across the whole. On the east, however, we have broad spurs that join on to the great sheet of Boulder Clay eastward and southward, and which are only separated from one another by the valley of the Lark and of its tributary from Ampton.

The greatest thickness of the Boulder Clay in the district is uncertain, we have no record beyond 50 feet, at Ingham (*see* p. 114); but probably over great part of its area this clay is of less thickness than the figure given.

Mr. Skertchly has remarked, in speaking of the large flints found in the Boulder Clay at Elvedon Lodge (*see* p. 70) that "it is very significant of the local origin of that deposit, that the flints are not cracked or weathered, and are suitable for knapping [some of them have been worked for gun-flints]. Had these stones travelled far, or been much exposed, they must have become weathered and unfit for knapping; but although striated they are as sound as ever, and the coats are not much reduced in thickness."*

Mr. Bennett notes that "in mapping the Boulder Clay from Bury St. Edmunds westward a change of character (from the normal condition on the east) became apparent. This was noticed in a privately printed postscript to a paper of 1884,† the substance of which is now reproduced."

"Further investigation has led me to change my view as to the reason for the difference in the Boulder Clay westward of Bury St. Edmunds, Thetford, &c. from that eastward of those places."

"In the former tract the clay lessens much in thickness, with a maximum of 25 feet, occurs in patches, is brown, sandy and very chalky, and contains many unworn flints and boulders of local origin. Outside this tract we find an almost unbroken sheet of the well-known bluish-grey clay, reaching a thickness of 100 feet, made up chiefly of chalk and flints in a clay-matrix, and with the usual assemblage of foreign (or distantly derived) boulders. Thus one seems to contain mostly local rocks, whilst the other is largely made up of foreign rocks. Along the line between these two kinds of clay there are sections showing them apparently interbedded."

"The conclusion I come to is that the two clays are the results of two glaciations. The thin sandy clay with local detritus seems to have come from the north-west, over a Neocomian and Chalk tract, and may have been formed by land-ice. The thick blue Boulder Clay, with foreign stones, may be due to a north-eastern glaciation. But the two were formed contemporaneously, as shown by the interbedding along the dividing line, which line was the meeting of the two glaciers."

Local Details.

From Sutton Boulder Clay stretches over the higher ground eastward to Witcham, and by Wentworth to Witchford. Mr. Skertchly says that "large masses of chalk are not peculiar to Roslyn Hole (to be described directly), for one occurs in the Boulder Clay in Witcham Fields, but it is of minor importance. At Little Hill, a mile N.W. of the last place, the Boulder Clay is light-brown and full of stones, chiefly chalk and flints. Hereabouts the Boulder Clay goes farther down the slope, towards West Fen, than it does nearer Ely."

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* Gun Flint Memoir, p. 14. 1879.

† "On the Glacial Question and the Drifts of East Anglia," *Proc. Norwich Geol. Soc.*, pt. viii., pp. 252–262. The postscript added to separate copies. 1886.

The next patch to the east is but just cut off by the little valley along which runs Grunty Fen Drain, and it caps most of the higher ground from the road between Witchford and Thetford northward to Ely. Mr. Skertchly notes that "a similar old valley (to that of Roslyn Pit) filled with Boulder Clay is intersected by the highway about half way between Witchford and Ely." Of the northern end of this patch he remarks that "the Boulder Clay on the eastern side of the high road, just out of Ely on the south, where the Witchford road joins, contain intercalated coarse gravel, merely a mass of veins in the Boulder Clay," but enough to be mapped as gravel.

Northward from Ely is another mass, to Chetisham and nearly to Downham, which gives one of the finest sections that have ever been seen, in the great pit of Roslyn or Roswell Hill, north-eastward of the city.

The following account of this important section (to p. 69) has been compiled from Mr. Skertchly's published description,* supplemented by his MS. notes, and with other additions.

The attention of local geologists has long been drawn to Roslyn Hole from the fact that various newer rocks (Boulder Clay, Chalk Marl, and Gault) there abut against the Kimeridge Clay, in which alone the north-eastern face of the pit is cut. The Gault has not been found in place within nearly three miles, and the nearest Chalk Marl is five miles off; their occurrence here, therefore, is remarkable enough. The result of this remarkable assemblage of rocks in so abnormal a position is that the pits have a literature of their own, valuable not merely for the theoretical views brought forward, but also as preserving a record of the changing aspects of the section.

Prof. Sedgwick published the first notice of Roslyn Holes in 1846,† ascribing the presence of the Chalk to a fault with a downthrow of about 150 feet which "took place immediately before the deposit of the *brown clay*" (Boulder Clay). This paper is illustrated with diagrams which show that the Kimeridge Clay now exposed upon the east of the pit was not then visible.

Prof. H. G. Seeley next described the section, in three papers, in 1864 and 1865,‡ but as he published a later article, in 1868, there is no need to refer to these, save as illustrating the history of the subject and to note that, in the first of them, he alludes to the view that the Chalk here is merely "a drifted mass, included in the Boulder clay;" but only to condemn it, on the ground that from "a section showing Kimmeridge Clay and Chalk side by side, and Boulder clay between them . . . . the conclusion inevitably followed that there had been a great fault, letting down the Chalk for at least two or three hundred feet:" reasoning that seems somewhat difficult to follow.

In 1867 the Rev. O. Fisher for the first time publicly brought forward the boulder-theory,§ urging that "the mere size of the mass of cretaceous strata at Ely is no argument against its having been carried thither by ice," noting that "the chalk thins out to nothing, the boulder clay passing beneath it," and concluding that the evidence "is against the occurrence of a fault, and points to the boulder clay

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* The Geology of the Fenland, pp. 236-241.

† *Rep. Brit. Assoc.* for 1845, *Sections*, p. 42.

‡ *Geol. Mag.*, vol. i., pp. 150–154, vol. ii., pp. 262, 265, 529–534.

§ *Proc. Camb. Phil. Soc.*, vol. ii., pt. iv., p. 51. Reprinted in *Geol. Mag.*, vol. v., pp. 407–411. (1868); and note on p. 438.

occupying a trough, which it has ploughed out for itself in the old sea bottom of Kimmeridge clay."

The next year PROF. SEELEY* again took up his pen, in defence of the theory that he had supported, and treated Mr. Fisher's view to some pleasant banter. He appealed to the existence of slickensides as in his favour, and illustrated his views with two sections, the one showing the beds as he saw and interpreted them at the last, and the other, of a highly ideal character, giving a restored view of the Cretaceous beds overlying Kimeridge Clay horizontally (before their denudation), and then plunging down almost vertically into the earth.

It was not until 1872, however, that the question of how the Cretaceous beds got here was set at rest, by PROF. BONNEY,† who had visited the pit from time to time in the foregoing three years. He gave four diagrammatic sections across the pit, from north to south, two of which clearly show Boulder Clay going beneath Gault, and a map showing the position of the beds in the floor of the pit. After supposing every circumstance favourable to simplicity he showed that the fault-theory needed most involved phenomena, such as two reversed faults with an ordinary downthrow-fault outside each (all later than the Boulder Clay and near together), and he said "I conclude, therefore, that this arrangement is so extraordinary that it renders the fault theory in the highest degree improbable. We are accordingly driven to consider this mass of Cretaceous rocks, as either slipped from above, or dropped as a boulder of gigantic size into a pre-existing valley. Though no doubt there have been slips from the cliffs on the south bank of this valley, I do not think that we can very well explain the position of this mass of Chalk . . . on the first of these theories." It is then noted that such large boulders are not unprecedented.

The further evidence to the same effect got during the progress of the Geological Survey was noted in a general memoir by MR. SKERTCHLY.‡

We may now describe the details of the section, as recorded by MR. SKERTCHLY, to which description but slight addition can be made, the southern side of the pit being little touched of late; and then we may show the bearing of the observed facts on the question of the boulder.

The great set of clay-pits known as Roslyn or Roswell Holes is about a mile E.N.E. of Ely Cathedral, beginning at the base of the narrow tongue of Lower Greensand and stretching in a south-easterly direction nearly from the top to the base of the slope of the Kimeridge Clay. The material is dug for the repair of the banks of the Bedford Level. The pits contain water to depths up to 25 feet, and the area is irregularly divided into four-sided portions, by banks left for the purpose, which can be examined from a boat, and were of great consequence in tracing the run of the beds, a work that needed some care, as the banks are now and then renewed with a capping of clay, which may be either Kimeridge Clay, Gault, or Boulder Clay.

A plan of the pits is given in Fig. 13, from a survey by myself. Chalk and Gault have been dropped into a narrow space, hollowed out of the Kimeridge Clay, and Boulder Clay was seen in place where marked.

The western end of Roslyn Pit cuts the boundary-line of the Lower Greensand, which formation occurs, indeed, in place in the fields to the west. In following this boundary we come suddenly upon the mass of Boulder Clay in question; and, if the section were not open, the contour of the ground would not lead to the discovery of the Drift beds. These beds, in fact, fill up a small valley which can be traced to the river on the east, and towards Little London on the west.

The pits can be most conveniently described in portions, which may be called the *Great*, *Middle*, and *Lower Pits*. The Great Pit lies to the

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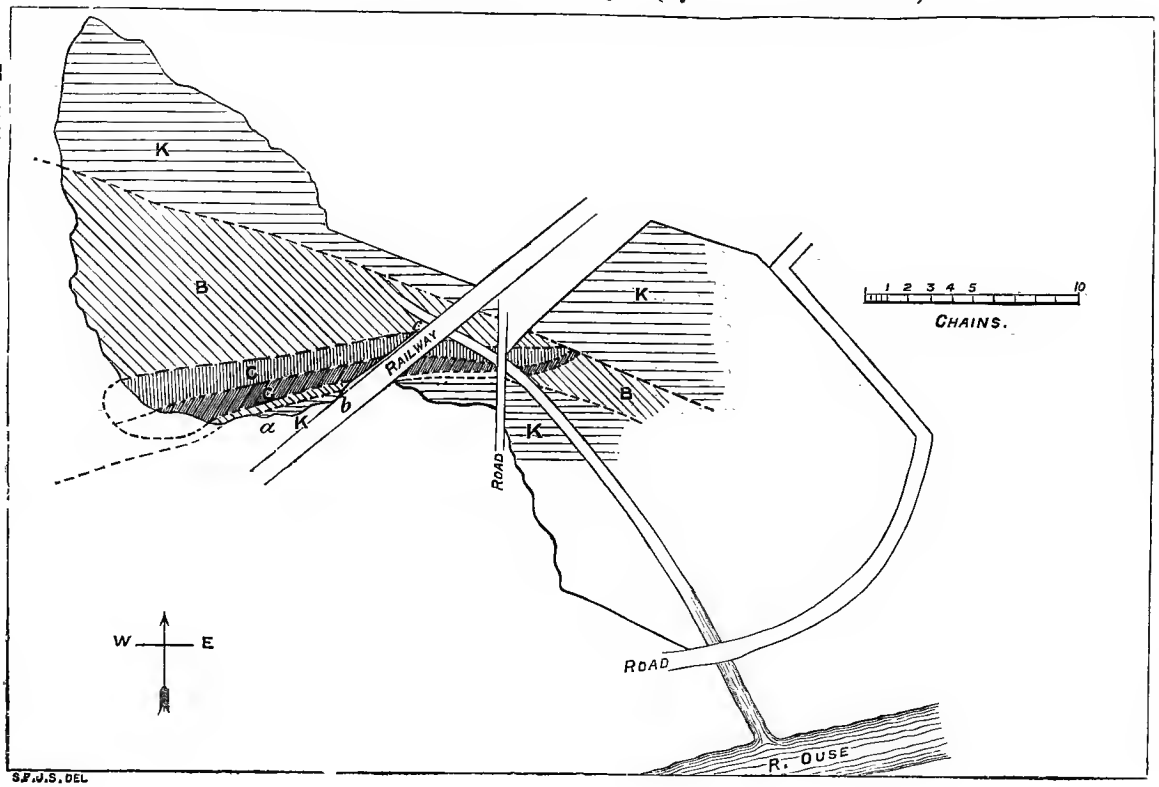
* *Geol. Mag.*, vol. v., pp. 347–349. (1868.)

† *Geol. Mag.*, vol. ix., pp. 403–408. For the most part reprinted in his "Cambridgeshire Geology," pp. 69–76. 8vo. *Cambridge*, 1875.

‡ The Geology of the Fenland, pp. 236–241. 1877. For the most part now reproduced (to p. 69).

FIG. 13.—*Plan of Roslyn Hole, Ely.* (By S. B. J. SKERTCHLY).



B. Boulder Clay.
C. Chalk.
G. Gault and Greensand.
K. Kimeridge Clay.
a. b. Site of Fig. 14.
c. Site of Fig. 15.
The extent of the great boulder is shown by the broken line enclosing C and G.

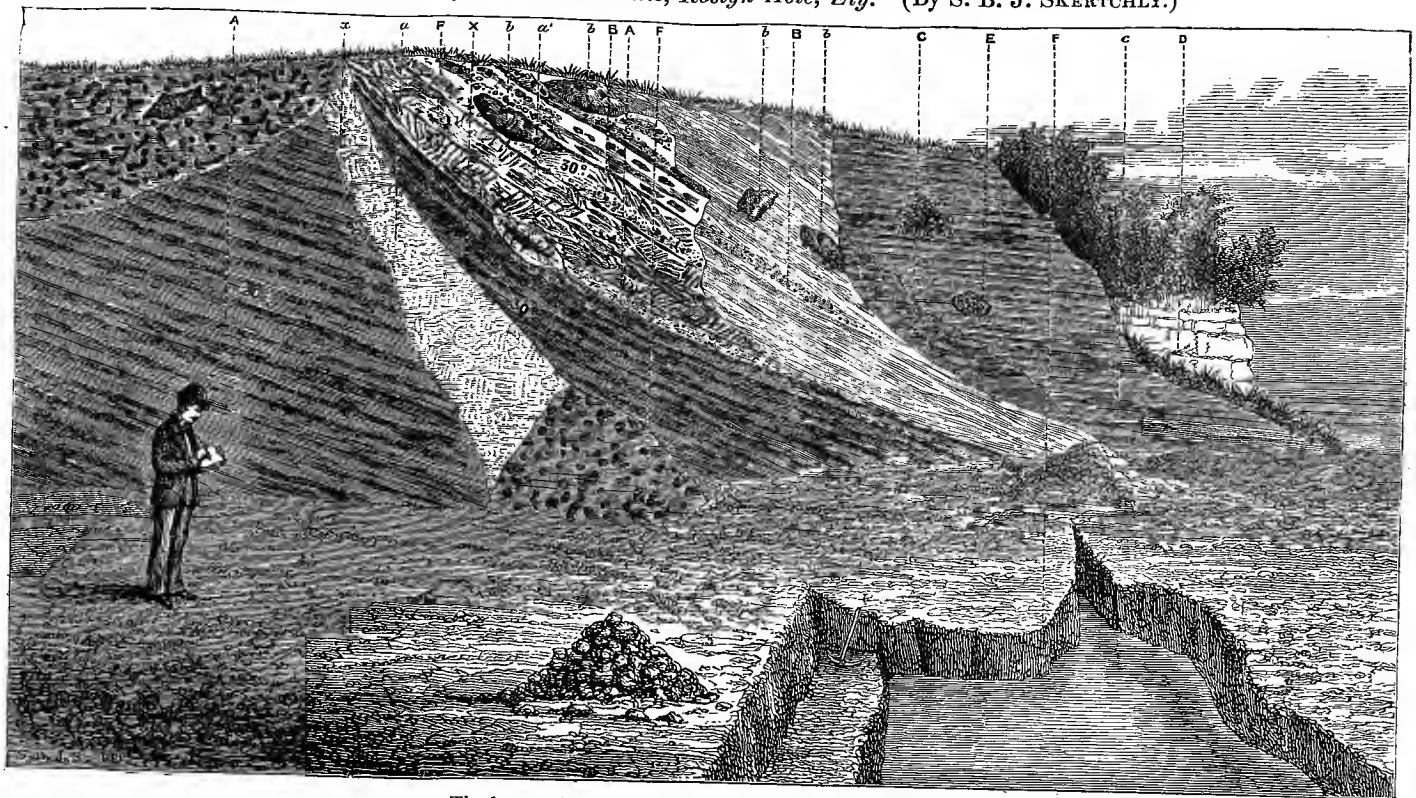
E

north-west of the railway, and is the one which has been so frequently described. In it the exposures are generally pretty clear. It now (? 1874, 5) measures 18 chains 44 feet by 7 chains 44 feet, and is approximately quadrilateral in shape. The Middle Pit lies between the railway and a by-road. It is roughly triangular in shape, the boundary along the railway measuring 4 chains 4 feet, and that at right angles nearly 3 chains 20 feet. The sections are much obscured by vegetation, but the different beds can be easily determined by working along the sides of the pit with a hammer. The Lower Pit comprises the rest of the opening, and is rudely circular in shape, with a diameter of about 15 chains. It lies chiefly at or near the level of the fen, and cuts the peat. Sections are very rarely exposed in it, the water seldom being low enough to allow of digging; but, owing to the dryness of the season, clay was dug from it in the summer of 1874, and I thus had an opportunity of studying its geological features.

In the Great Pit the Kimeridge Clay is seen in place along the north-eastern side, the southern half of the south-western side, and the eastern half of the north-western side. It is nearly horizontal over most of the pits, but on the south-western side it is bent downward toward the great erratic, as if by its weight, attaining an angle of 20° near the junction, as shown in Fig. 14. The junction of this clay with the Boulder Clay on the north-western side of the pit is obscured by herbage, but the position is indicated by springs. Near the railway the Kimeridge Clay is seen to be bent down as before described, and as shown in Fig. 15. The Neocomian Sands are not seen in place in the pit, but a fragment dipping at an angle of 30° was exposed in 1874, and is shown in Fig. 14. From this point, going northward, we come upon the great boulder—Gault, Greensand (base of the Chalk), and Chalk succeeding each other in stratigraphical order. It is partly owing to this preservation of geological position that the idea of faulting arose; but one peculiarity has not been noticed, namely, that the dip of the Neocomian beds is about 30° to the east, whereas the newer beds are either horizontal or dip slightly to the south-east, which can hardly be accounted for on the theory of a fault. Again, as the figure shows, not merely the Neocomian Sands but part of the Kimeridge Clay itself is seen to be separated from the main mass and to dip with the sands. Both these rocks are in place close at hand, whereas the Upper Cretaceous rocks are foreign to the locality, and the mode in which the former dip is very suggestive of a crushing, dragging weight, such as the boulder would produce. It will, furthermore, be seen that the Kimeridge Clay does not abut at once upon the erratic mass, but is separated from it by a mass of shattered Kimeridge Clay, which for brevity we will call "shattered clay." Against this shattered clay the Kimeridge Clay abuts, and the junction is a sharp line inclining at an angle of 60°, with beautifully slickensided faces; and a similar fault-like plane bounds the shattered clay upon the other side, with an incline of 30°. It must have been some such appearance which led PROF. SEELEY to assert that he had seen actual fault-planes; but anyone who carefully studies them will see that they cannot in any degree, supposing them to be faults, account for the phenomena; firstly, because the two must have faulted-in the shattered clay which lies between them; secondly, from their hade they would cause an *upthrow* and bring up lower beds of Kimeridge Clay; and thirdly, they could not account for the difference of dip between the Neocomian and other Cretaceous rocks; moreover, it would be necessary to suppose other faults on the opposite side of the pit, only a few yards distant, to bring the Kimeridge Clay back to its original position. I am confident such faults do not exist, or they would be traceable across country. These supposed faults again must have been more recent in date than the Boulder Clay for they partake of every flexure and peculiarity of the Cretaceous rocks.

Fig. 15 is a view of the great boulder, close to the railway, the Kimeridge Clay on the left being bent down as before described. The Boulder Clay is here seen to lie between the Kimeridge Clay and the Gault, and further to the right than the illustration extends it occupies a similar position.

FIG. 14.—*Section of the Great Erratic, Roslyn Hole, Ely.* (By S. B. J. SKERTCHLY.)



The letters, beginning from the left, mean as follows :—

A. Kimeridge Clay (two places). *x*, × Supposed Faults. *a*. Shattered clay. F. Boulder Clay (two places). *b*. Lower Greensand Rock-bed, out of place (four places). *a'*. Septaria, out of place. B. Seams of Boulder Clay (two places). C. Gault. E. Fragment of the greensand-bed from the base of the Chalk. *c*. (?) not explained in the Fenland Memoir. ? Gault. D. Chalk.

Crossing the railway into the middle pit we again find the Chalk and Gault flanked by Boulder Clay, which lies in a hollow in the Kimeridge Clay. The sections are obscure, but the beds can be determined with a little trouble.

The great boulder does not extend into the lower pit, but the Boulder Clay reaches the river in a narrow band, with Kimeridge Clay on each side.

In thus working round the pit it is seen that everywhere Boulder Clay is interposed between the great boulder and the undisturbed Kimeridge Clay, that the Boulder Clay is always found below the great boulder whenever its base can be seen, that the limits of the great boulder lie within the pits, so that it is bedded in Boulder Clay; and lastly, that the Boulder Clay fills a small valley in the Kimeridge Clay.

If we look upon the Chalk and Gault as a great boulder, and picture what must have been the effects of so huge a mass being transported by or under ice, all the phenomena of the pits receive ready explanations, nor can we be surprised that the Neocomian Sands and Kimeridge Clay of the immediate neighbourhood were dragged out of place and toppled into the little valley, as shown in the figure. Neither should it surprise us that in places the Kimeridge Clay is bent under the weight of the transported mass, or that it should be cut away and the faces of the incision polished by the same agent. I say in places, for these supposed fault-planes are very local. The presence of shattered clay, again, is readily accounted for, it being in fact nothing less than incipient Boulder Clay.

That the rocks in question are not so perfectly in their natural condition as the advocates of the fault-theory assume is also shown by the section illustrated in Fig. 14. A seam of Boulder Clay is seen intercalated in the Neocomian Sands; a block of Neocomian conglomerate is imbedded in the said sands quite out of its normal position; and lastly, a mass of greensand (from the base of the Chalk) is similary lodged in the Gault clay. The facts show that the rocks have been disturbed, but not at all in the manner that faulted masses are dislodged.

The most direct proof of the erratic nature of the whole mass is that the Boulder Clay can, in favourable seasons, be traced beneath the mass and nearly all round it. Once more recurring to Fig. 14 it is seen that Boulder Clay occurs beneath the Kimeridge Clay and the shattered clay, and the pit in the foreground was dug through shattered clay into chalky Boulder Clay. By traversing the pits in a boat I was able to trace the shattered clay underneath the Gault and Chalk, and at more than one point the Boulder Clay was seen beneath the shattered clay. Moreover, from seeing various pits dug, which were dry for a few days only, *I have seen Boulder Clay underlying all the Cretaceous rocks*, and it can still be seen cropping out on all sides of the mass.

If any doubts remain as to which view is correct, they must be at once removed by Prof. Bonney's exhaustive examination of the possibilities of faulting.* Such an extraordinary complication of faults is required, and the faults would be crowded into so limited a space, that this hypothesis must be abandoned. The examination of the surrounding district, and frequent observations in the pits, which I carefully watched during a two years' residence at Ely, convinces me that no arrangement of faults could possibly bring the beds into their present position.

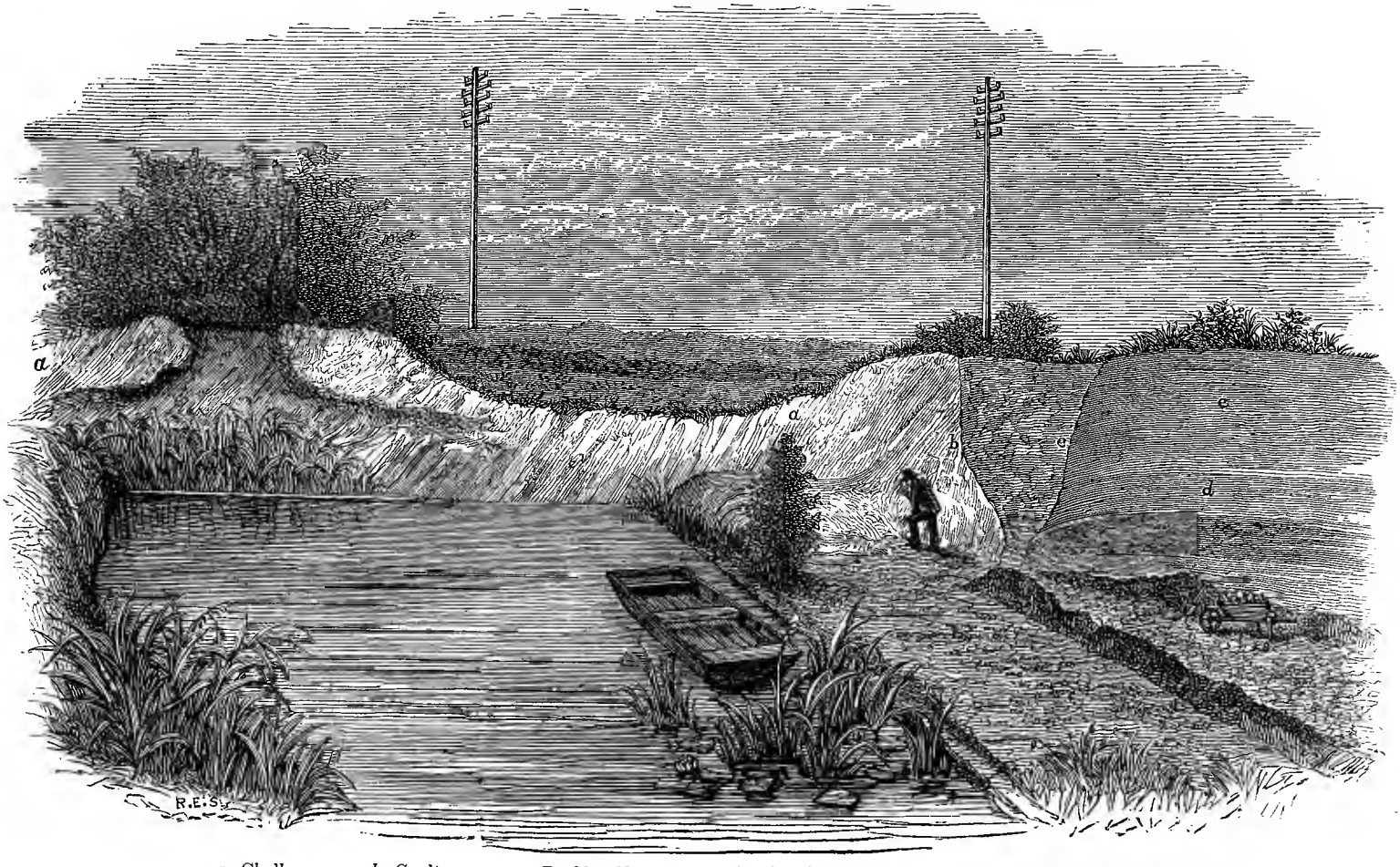
S.B.J.S.

Mr. Skertchly notes the occurrence of a small patch of sandy gravel at New Barns, north-eastward of Ely, which gives rise to a strong spring. He describes it as full of angular flints and of pebbles of hard chalk, with a few ironstone-nodules, from the Lower Greensand, and he regards it as merely a sandy facies of the Boulder Clay, the latter, in the neighbourhood, being brown and full of like stones.

"On the road leading towards Chetisham, from the Downham road [? about ½ or 1½ miles northward of Ely] is a boulder of gneissic granite,

* *Geol. Mag.*, vol. ix., p. 403, and "Cambridgeshire Geology," p. 69.

FIG. 15.—*Section of the Chalk Boulder at Roslyn Hole, Ely.* (By S. B. J. SKERTCHLY.)



a. Chalk. *b*. Gault. *c*. Boulder Clay. *d*. Kimeridge Clay. *e*. Kimeridge Clay, disturbed.

with smooth but not striated sides, measuring about a foot each way. Many boulders of about the same size were seen (in 1874) at the new farmstead on the by-way to West Fen, north of the windmills on the Downham road, and these consisted of granite like that above-mentioned, of dark grey fine-grained basalt, of Neocomian sandstone, and of a fine sandstone with black markings, all being markedly smoothed."

"The Boulder Clay between Downham and Chetisham seems to be very pure [free from stone], and is difficult to distinguish from Kimeridge Clay."

Of the various small patches of Boulder Clay scattered over the district there is nothing to be said. The boundary of the main mass enters the district, on the south, about $1\frac{1}{4}$ miles W. of Risby Church, whence it runs northward to near Cavenham, where it is hidden under River Gravel and Alluvium for some way eastward, up the left side of the Valley of the Lark, until it emerges again at Fornham All Saints. Appearing again along the right bank of the river the boundary is cut back along the valley of the tributary stream from Livermere Park.

From the northern side of that stream, at Culford Park, the boundary wanders irregularly northward and north-westward, leaving the Valley of the Lark near the Icklinghams and reaching our northern limit at Downham High Lodge. Over the greater part of this course the boundary is doubtful, on account of the thin sandy covering which spreads alike over the Boulder Clay and over the Chalk, and which often so alters the character of the ground that the presence of clay would not be suspected until a section is seen.

From Downham High Lodge the boundary runs irregularly south-eastward, over the high ground, until, getting to a lower level in the valley of the Little Ouse, it passes out of the district at Barnham St. Gregory, and in this course, too, it is much hidden by sand.

Mr. Bennett notes that "two pits, on the south-western side of the road, more than three eighths and about five eighths of a mile S.E. of Flempton Church, showed sandy and gravelly soil over light-brown Boulder Clay."

The two following notes are by Mr. Blake:—

"East of the curved point of Hengrave Hyde Wood, about $1\frac{1}{4}$ miles southward of Hengrave Church, a pit showed a thickness of 9 or 10 feet of bluish Boulder Clay, which contained, besides chalk pebbles, many boulders of various rocks, some more or less angular, others well rounded. Five feet down was an undulating layer of fine stratified buff sand, a foot thick."

"In a clay-pit in the north-eastern corner of a field about half a mile N.E. of Fornham St. Martin Church, a little sand and gravel, with many quartz pebbles, was seen intermixed with the Boulder Clay; and, in one part, Boulder Clay, seven feet thick, was seen over chalk-rubble, to the same thickness, with flints and in places a little Boulder Clay."

Mr. Skertchly has made the following notes of pits along the western side of the long northern spur:—

"On Elvedon Warren light-yellow Boulder Clay was seen, in a few pits, to a depth of not more than seven feet, on Chalk, and in some places apparently on sand."

"Southward [? south-eastward] of Elvedon Lodge there was, in 1875, a fine pit, about 18 feet deep, showing on the southern side sand, with very few flints or other stones, to an average depth of eight feet, lying unevenly

on Boulder Clay. The upper seven feet were a rich ferruginous brown and grey, here and there apparently contorted, but not laminated. The bottom foot had about 26 fine layers of greenish clay, laminated and slightly waved or puckered. At the base of this was a layer of small sub-angular flints. The Boulder Clay contained well-striated boulders, and one septarian stone, measuring $27 \times 18 \times 13$ inches, was strongly scored and scratched, some of the groves being an eighth of an inch deep. Large flints, with the cherty coat scored, were plentiful, but foreign rocks were rare. The western side of the pit showed less of the sand, and this was laminated in patches only. On the northern side the sand was much mixed with the Boulder Clay, but there was a definite, though irregular, parting between this mixed clay and sand and the Boulder Clay below."

"The large pit [? marked on the map] behind May Day Farm, south of the eastern corner of Brandon Park, was about 20 feet deep, in 1875, and mostly in Boulder Clay. The overlying sandy gravel rests irregularly on the clay, but seems to be interbedded with it in places, though it is difficult to say whether these occurrences are not intersected pipes, the section being obscure. In the sand I found a sling-stone and a piece of a core. The Boulder Clay yielded well-striated septarian boulders, and on the southern side of the pit there was a very large boulder, or pinnacle, of chalk, two yards wide, but with the base hidden by talus. Brownish brickearth, with traces of lamination, occurred in the clay, towards the top."

In a clay-pit close to the western end of the patch of loam at Elvedon Gap, north-eastward of the village, there were large flints lying about, which clearly came from the Boulder Clay. Close to the eastern end of the loam another small pit showed sandy Boulder Clay, and the like was seen at the gasworks, in an old pit or pond a little west of Elvedon Church.

At Thetford Warren Lodge, on the chalk tract north-westward of Thetford, there may be a slight trace of Boulder Clay, but nothing was seen to justify mapping any.

Other sections of Boulder Clay have already been described, in treating of underlying beds, and some will be noticed in the sequel.

Gravel, &c. above the Boulder Clay.

In the eastern part of the district there are some patches of gravel, generally coarse, with occasional sand, which seem to ally themselves rather with the Cannon-shot Gravel near Norwich than with any River Gravels, and which, though overlying Boulder Clay, seem to have more kinship therewith than with the newer Drifts. These have therefore been coloured as Glacial.

Mr. Blake notes that "coarse flint gravel, averaging about 8 feet in thickness, irregularly overlies the chalk in the cutting three eighths of a mile south-east of Fornham St. Martin Church," and again "a thickness of about 10 feet of gravel and sand, very irregularly intermixed, and resting on chalk, was seen in the excavation for the railway-bridge over the road about a quarter of a mile east of the church, the foundations of the bridge being on chalk."

In the cutting to the north there is, above the Boulder Clay, a sandy soil, up to six feet thick south of the bridge.

At Ingham a good section was given by the railway-cutting, in 1873. South of the southern bridge a hollow of gravel and sand was shown, and north of the bridge another of sand and gravel. The Boulder Clay is then at the surface for a little way, and many large boulders occurred in it. Northward, however, it falls, gravel and sand coming on above, with a thin layer of clean clay between them and the Boulder Clay at the northern bridge. Mr. Bennett noted that the gravel here is very coarse, consists mostly of large flints (but with some boulders of greenstone), and is 15 feet thick at the deepest.

The gravel at Ingham Heath, over two miles to the north, is presumably of the same age, and the sand on the hill-top north of Thetford has been doubtfully so classed.

CHAPTER VII. POST GLACIAL DRIFT.

It should be understood that the term Post Glacial is here used in a purely local sense, for deposits formed after the Glacial Drift of the district; but not needfully after the Glacial Drift of more northern parts, where ice-action lingered longer than in more favoured southern tracts.

Gravels of Ancient Rivers.

In the Cambridge Memoir certain beds, usually occurring at high levels, and with no relation to existing river-valleys, were described as Gravels of Ancient Rivers.* Some of the gravel of our present district seems to range itself under this heading rather than under any other.

Mr. Skertchly says "A line of patches of these gravels, at a height of about 70 feet above the level of the Fens, has been mapped from south of Mildenhall, across the valley of the Lark to above Lakenheath. The gravel now occurs as cappings to the hills, preserved in slight hollows that once formed the bed of the old river, the drainage-system having been wholly changed since its deposition."

Dr. J. Evans is disposed to regard the part of this line of gravel patches north of Mildenhall as "the ancient representative of the River Lark" which seems "to have proceeded northward by Eriswell and Lakenheath, to join the Little Ouse."†

The patch at Snailwell, however, is probably an extension of the same line south-westward, and then, as Mr. Skertchly puts it, "these gravels follow a line almost at right angles to the present rivers, and they extend right across the Kennet, the Lark and the Ouse (in Sheet 65, to the north), so that they are clearly independent of the present rivers."

The patch of gravel that occurs from between Landwade and Snailwell southward, in a long narrow ridge to just beyond the edge of Sheet 51, N.E., has been classed under this head, as Mr. Jukes-Browne tells me, "because it seemed to tail on to gravel from Newmarket to Exning (in 51, S.E.); but possibly that part near the Alluvium has been re-constructed by the more modern stream." The classification seems doubtful, and possibly this gravel should be treated under the following heading, as pertaining rather to the valley of a modern stream; but it should be

* The Geology of the Neighbourhood of Cambridge, pp. 82–93. (1881.) Following Mr. Jukes-Browne's Essay on the Post-Tertiary Deposits of Cambridgeshire. 8vo. *Cambridge*, 1878.

† The Ancient Stone Implements . . . of Great Britain, p. 596. *See also* p. 494. (1872.)

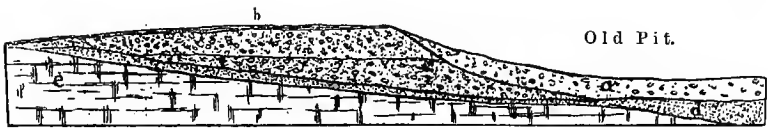
remembered that it is often very difficult to be sure in defining the age of isolated masses of gravel.

I was fortunate in seeing the railway-cutting through the northern end of this patch at about its best, when the sketch shown by Fig. 16 was made. I was told that an elephant's tusk was found in the gravel.

Half a mile southward of the cutting is an old pit (wrongly marked Clunch Pit on the old Ordnance Map) in chalky gravel and sand.

FIG. 16.

Section of Part of the Cutting on the Newmarket and Ely Railway between Landwade and Snailwell.



a. Rubbish in the bottom of old pit.
b. Gravel, of angular flints in a chalky matrix, up to about 5 feet thick (with soil).
c. Gravel, of chalk pebbles (rather large) and flints, sandy, up to about 5 feet thick. Dips towards the valley.
d. Light-brown or buff sand, with some small pebbles of chalk and of flint; from very little up to 3 feet thick; thickens to 5 feet just beyond (S.E.).
e. Chalk.

MR. BENNETT notes that "there is a patch of this gravel capping the hill from above Snailwell eastward, for more than a mile. The large pit, marked on the map, about a quarter of a mile south-eastward of the church, showed a thickness of 10 feet of rather coarse gravel with a chalky matrix; the larger stones are mostly much rolled flints, there are also pebbles of flint and of hard chalk, and most of the small pebbles are of chalk. In parts the gravel was finer, and in one place there were signs of bedding, though elsewhere there were none." I saw some earth here that was not unlike weathered Boulder Clay.

"In the mass that caps Barton Hill, south of Mildenhall, the pits were mostly not more than 3 feet deep, in coarse subangular gravel, but just north of the road to Tuddenham, by the windmill at the eastern end of the patch, there was a pit in gravel, much like that of Snailwell and giving the following section":—

Sandy soil, with rather large flints; a foot.
Rather fine chalky gravel, with bedded and false-bedded sand; at the base an irregular bed of pebbles; 2 feet.
Coarse gravel with more flints than the above, but still largely made up of chalk: some of the flints much worn, some very little; a foot to 2 feet.

MR. A. G. WRIGHT tells me (1888) that in a pit southward of the two Tumuli, marked on the map, at the western end of the patch, four or five implements were found, at a depth of not more than 2 feet, according to the workmen who brought them to him; and he describes them as small, roughly chipped, and showing the crust of the flint on both sides.

The gravel of Warren Hill, east of Mildenhall, has been classed with this series. It is important as having yielded many flint implements, and DR. EVANS remarks that "there are great numbers of quartzite pebbles, as well as very many formed from rolled chalk, mixed with the other constituents. These are less abundant in the upper part of the deposit, which is there of considerable thickness . . The gravel beds are in places as much as 14 or 15 feet in thickness. Mammalian remains are scarce, but . . . the core of the horn of an ox, and teeth of horse, and teeth of elephant" have been found. Moreover, the REV. CANON GREENWELL "has found . . . several of the quartzite pebbles bearing evident marks of abrasion and bruising at the ends, such as may have resulted from their having been in use as hammer-stones. . . . He has also an

ovate lanceolate implement from this spot, 4¾ inches in length, and formed from a quartzite pebble, the original surface of which is still preserved over nearly the whole extent of one of the faces." Implements "of oval form are especially abundant. . . . A very large flake, rounded into a broad scraper, and about 5 inches in diameter, was found by myself . . . and is now in the Christy collection."* Mr. A. G. Wright also has an implement of quartzite from here.

Codson Hill, S.E. of Eriswell, is capped by some gravel of the same series.

Mr. Skertchly notes that "the gravel may be well seen on Mareway or Portway Hill, eastward of Eriswell," where there is a larger mass. He adds, "I know of only one flint implement from here," and gives the following details:—

"At the chalk-pit, marked on the map, by the high road E. of Eriswell, the section is as follows (1875)":—

Gravel, like that in the pit next to be described, with much chalk: The sand is always reddened at the surface and at its contact with the Chalk. The gravel, which is not bedded and has many stones on end, varies from 2 to 6 feet in thickness, and rests irregularly on the Chalk.

Chalk, with a layer of pipe-clay about 10 feet from the surface, showing an easterly dip of about 2°.

"Northward, a pit, 4 feet deep, showed the sandy matrix of the gravel stained red for about a foot down, below which it was white and chalky. The gravel was full of weathered angular flints, mostly small, and contained many pebbles of quartzite and of Coal Measure sandstone."

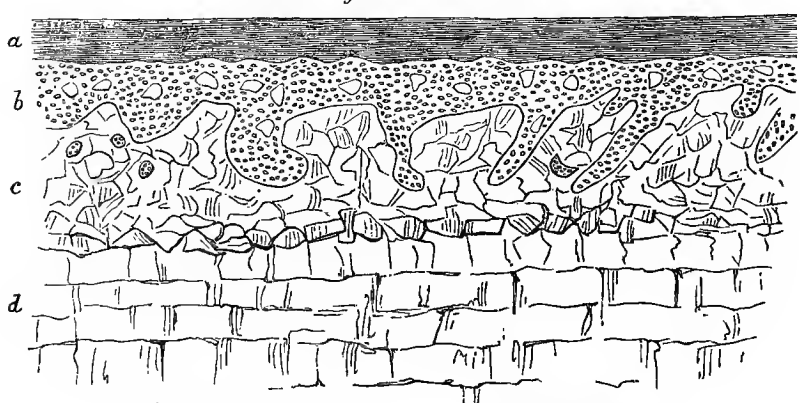
"Still further northward, at the abandoned chalk-pit, marked on the map, on the western side of the high road, the junction of the Chalk and the gravel was again shown."

The next patch to the north is on the hill eastward of Lakenheath, from Maids Cross southward. This spot, according to Mr. J. W. Flower and Dr. Evans, is locally known as The Broom. The gravel is 8 to 10 feet thick, and "several well-fashioned implements have been found in it, mostly of pointed form."† Mr. A. G. Wright has a quartzite-implement from here.

Mr. Skertchly has remarked that "the surface of the Chalk further inland is worn into the curious curves so well known to workers in chalk-districts. Fig. 17 is an outline-drawing of one such case."

Fig. 17.

Chalk-surface at Lakenheath.



a. Soil.
b. Chalk-rubble and Gravel.
c. Rubbly chalk.
d. Solid chalk.

* The Ancient Stone Implements . . . of Great Britain, pp. 488–490, 492.

† *Quart. Journ. Geol. Soc.*, vol. xxv., pp. 450, 451. (1869) and "Ancient Stone Implements," pp. 511, 512.

Mr. H. B. Woodward took the following notes of the gravel N. of Long Stanton, in the southern part of map 51, N.W. and beyond our present district, in 1881, after the publication of the Cambridge Memoir, in which that gravel is described.

"North of the Railway Station some newly made ditches, by the road-side, showed a thickness of 4 feet of fine gravel (flint, quartz, &c.) resting on grey and brown brickearth, with 'race' and small pebbles. Freshly-cut drains in an adjoining field, a quarter of a mile N.E. of the station, showed gravel and occasionally brickearth, 3 to 4 feet thick, from the road to the summit of the low ridge on the east. On Mr. Penning's working-map lines have been drawn to connect the Willingham and Long Stanton gravels; but evidently at the time there was no positive evidence, and he thought it best to keep them separate, which was done on the published map. Now, however, they may be united, with the addition of a little more gravel on the west."

"South of the Mill, between Willingham and Long Stanton Station, a new ditch showed 3 feet of gravelly brickearth on the western side of the road; and I have extended the gravel a little in this direction."

River Drift.

We now come to the consideration of beds that seem to be connected with the present valleys, although they must have been formed in great part at a time before those valleys had been cut to their present depth, and when their streams were more powerful than those of the present time. The reader who wishes for a fairly full history of the research on these Drifts is referred to the Memoir in which the most important in the country, those of the Thames, are described,* and for an account of the evidence of man's existence at the time of their deposit to the great work of Dr. Evans.†

It is the occurrence of flint implements, fashioned by man's hands, and sometimes associated with the remains of extinct mammals, that has given a great interest to these deposits.

The River Drift of our district consists mostly of gravel, with sand; but there are here and there patches of loam, which are shown separately, where they are distinct enough to be mapped.

The difficulty that often occurs in classifying gravels has already been alluded to, and in some cases, therefore, the grouping adopted must be understood to be doubtful.

Valley of the Kennett.

Mr. Bennett, who mapped this tract, remarks that "the spread of gravel from Kentford to Fordham has been separated by the river from that reaching from Freckenham to the Valley of the Lark, leaving a strip of bare Chalk sometimes nearly a mile wide between. These gravels contain

* The Geology of London and of Part of the Thames Valley, vol. i., chaps. 20, 21. (1889.)

† The Ancient Stone Implements . . . of Great Britain, chaps. xxiii.–xxv. (1872.)

patches of loam in places." How much, therefore, of the gravel should be relegated to the old Kennett, and how much to the old Lark is somewhat doubtful.

In 1886 Mr. A. G. Wright recorded the finding of flint implements near Kentford,* and in 1889 he repeated his remarks, with additions and with figures of seven implements.† From these accounts, and from a letter from Mr. Wright, the following paragraph has been compiled:—

In the winter of 1884, 85, a number of implements and flakes were found in a pit worked for ballast by the Great Eastern Railway Co., on the southern side of the line about three quarters of a mile east of Kentford Church. A quantity of mammalian remains were also found, and these Mr. Wright sent to the Woodwardian Museum, Cambridge. Some of the implements were secured by him, from the workmen, and others by Mr. Prigg, of Bury St. Edmunds; some are waterworn, but in others the angles and edges are as sharp as when made.

Prof. T. McK. Hughes writes to me that the bones were, for the most part, too fragmentary for specific determination, and that those named are as follows:—*Bos, Cervus, Elephas primigenius, Equus, Hippopotamus,* and *Rhinoceros*.

Mr. Bennett visited the pit in 1890, and took the following notes:—"On the south of the railway a pit has been worked for 13 chains in length, and up to 18 feet in depth, the floor sloping down from W. to E., and the section being as follows":—

Gravel and rolled flints, with a few boulders of quartzite, obscurely bedded in places; up to 10 feet thick.
Gravel, almost wholly of chalk-pebbles, with layers of chalky false-bedded sand, passing into pipe-clay.

"At the eastern end there was a lenticular mass of loam and loamy sand, 4 feet thick at most, and several feet long."

"The coarse upper gravel could hardly be the result of the decalcification of the lower gravel, which consists chiefly of chalk, and the former seems to rest on the flanks of the latter, as if the two had been deposited by the old river at different times and under different conditions. Moreover flint implements and elephants' teeth have been found in the upper, but not in the lower, gravel."

"Ballast was being worked north of the railway, at the time of my visit, also for a length of about 13 chains, of much the same depth throughout, and wholly in the upper gravel, which is without sign of bedding: it is said to have been worked to the depth of 18 feet, without reaching the bottom."

This gravel is an isolated patch.

Continuing from Mr. Bennett's older notes:—"The railway-cutting N.E. of Kentford gives the following section":—

Very fine clayey [and chalky?] cream-coloured sand, drying white, passing into the next; 0 to 7 feet.
Laminated buff sandy loam; 0 to 4 feet.
Coarse unstratified pebbly flint gravel, with very many small chalk-pebbles; up to 14 feet seen.

"Both the sand and the loam contain fragments of shells, and a fish-vertebra was also found. These beds scoop into the gravel."

A pit, about three eighths of a mile north of Kentford Church, showed "3 feet of coarse sub-angular flint-gravel, with pebbles of quartzite, overlying fine bedded sand, seen to the depth of 2 feet;" whilst another pit, just N.W., showed "5 feet of much worn, rather coarse, flint gravel, with a little chalk, roughly bedded by layers of fine buff sand."

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* *Nature*, vol. xxxiv., pp. 521, 522.

† On the Discovery of Palæolithic Implements in the Neighbourhood of Kennet, Cambs. Pp. 2, 9 plates. 4to. *Privately printed.*

The pit marked on the map, "a little south of Kennet Church, is in sub-angular flint-gravel."

Mr. A. G. Wright, in the communications above-mentioned, has recorded the finding of three flint implements (which he figures) near Kennet, in 1886, on the surface of a field called the Shambles, not far from the high road from Newmarket to Thetford, and he adds that two other implements have been found on the surface near the same village.

Returning to Mr. Bennett's notes:—"There is subangular flint-gravel over Kennet Heath, and about three eighths of a mile southward of where the high road crosses the stream a pit showed a thickness of 5 feet of such, with sand."

Of the loam mapped over this spread of gravel, W. and N.W. of Kennet, he remarks that "it occurs in the gravel, and differs little from some of the Glacial loam. It has been dug around Kennet Church." A pit was seen in laminated buff loam on the northern side of the road, S.W. of the church.

"In the patch to the west (south of the Heath) there were several small pits in stiff clean buff loam."

"Near La Hague Farm, and nearly 1½ miles westward of the church, a deep pit showed buff sandy loam resting on grey and buff laminated clay."

"One and a half miles N.W. of Kennet Church buff sandy loam was again seen in a pit."

The old pit, marked on the map, a quarter of a mile north-eastward of Chippenham Church "seems to have been worked very irregularly. Where seen the gravel varied much: in one place it was coarse, sub-angular, with fine white sand (containing grains of chalk) beneath; both above and below was a patch of pinkish-brown clay, with chalk and some flints, somewhat like Boulder Clay."

"In Chippenham Field, and over a mile N.N.W. of the church, is an old overgrown pit, said to have been worked to the depth of 60 feet before chalk was touched. The gravel is sandy and contains patches of marl."

"About an eighth of a mile east of Fordham Church a much overgrown pit showed a thickness of 12 feet of sand and gravel, with a little marl, over the Chalk."

Valley of the Lark.

It will be convenient to follow a course up the left, or southern, side of this valley, where the gravel almost joins that just described, and then down the right side. The broad spreads of gravel are on the left side, and on the other it is only near the junction of the Culford tributary-stream that any large area occurs.

Perhaps the small patch at the north-eastern end of Thorney may be taken as belonging to the Valley of the Lark. Mr. Skertchly describes this as "a sandy deposit which might be mistaken for Lower Greensand brought down by a fault; but which, on examination, is found to be merely a reconstructed mass of the sand, lying on the Kimeridge Clay. A like mass occurs to the south at the north-eastern end of the next island, Stuntney." Perhaps these patches of sand are rain-wash, rather than River Drift.

Northward and eastward of Soham a sheet of Drift borders the Fen, wrapping round the Gault and the Chalk Marl. Mr. Skertchly describes this as "a thin deposit of sandy gravel," but at East Fen Common as "chiefly fine sand interspersed with brown and red flints."

Northward and eastward of Freckenham is a broad mass of gravel, but little separated from that on the other side of the Kennett at that village. It has been worked near its southern end, about 1½ miles south of Worlington, and also near that village, and a good section was opened on the Mildenhall Railway there, in the deepest cutting on that line, of which the following note has been contributed by MR. W. HILL:—"The Drift seems to be wholly composed of yellowish sand, of angular and rounded fragments of flint, and of rounded pieces of chalk. It has apparently been deposited against, and partially covers, the ridge formed by the outcrop of the Melbourn Rock, and it is 18 feet thick. MR. FENTON, a curiosity-dealer at Mildenhall, told me that many bones, &c., were found in it."

But barely separated from the above, near Worlington House, is a smaller patch, which skirts the marsh to above Little Barton. MR. A. G. WRIGHT tells me that he has a flint implement from the gravel at Barton Mills.

MR. BENNETT notes a section, three quarters of a mile N.E. of Herringswell Church, "in which the gravel seems to be banked against the Chalk. The upper part of the former is coarse, the lower part finer and bedded, the whole being mostly composed of chalk-pebbles, some large, with a few flints: the greatest depth seen was 7 feet."

Of the large mass over Tuddenham and Cavenham Heaths MR. BENNETT says that the latter place "is covered with fine buff sand, whilst at the southern end of the spur to the east, a pit, more than half a mile E.N.E. of Cavenham Church showed 5 feet of coarse gravel." MR. A. G. WRIGHT has a large flint implement from the gravel of Cavenham Heath.

From just below Flempton a strip of gravel and loam borders the marsh upwards to beyond our district. PROF. PRESTWICH has said "At Flempton I discovered in this gravel a small fragment of some mammalian bone . . . The gravel is composed chiefly of sub-angular flints in an ochreous sandy matrix . . . with . . . a considerable number of siliceous pebbles from the . . . New Red Sandstone, with pebbles of the older rocks, and fragments derived from the boulder clay . . . It is spread out in rough irregular beds interstratified with seams of sand,"* and again "At Flempton we found, mixed up in the flint gravel, large blocks of half a ton weight of basalt and hard sandstones derived from the Boulder Clay."†

MR. BENNETT says that "the loam mapped at Hengrave comes against the Boulder Clay, but there no section showed the relation of the two. Near the Hall, and northward, were pits in stiff clean grey loam. The moat round the Hall is in the like, and the bricks of which the house is built were made from the earth dug out of it."

Turning to the right side of the Lark, gravel borders the marsh from Fornham St. Genevieve to near Icklingham broadening out a little below the former village and forming the spur of Stow Heath Plantation, between the main stream and the tributary. MR. BENNETT describes this as "coarse red sandy gravel," and has mapped an extension up the tributary-valley, by Culford and Timworth, to the lower part of Ampton Park. He notes that "east of Culford is a patch of loam, in which are a few pits, one, a little west of the high road and near the stream, showing about 4 feet of buff laminated loam, which has been worked for brick-making," and he adds, from a visit in 1890, that "coarse shingly gravel was shown in widening the canal, for the revived navigation, opposite to and west of Babwell Friary," just beyond our southern border.

"At the junction of the road a little north of West Stow Church, a pit showed a thickness of 12 feet of sub-angular gravel and sand, with pebbles of quartzite."

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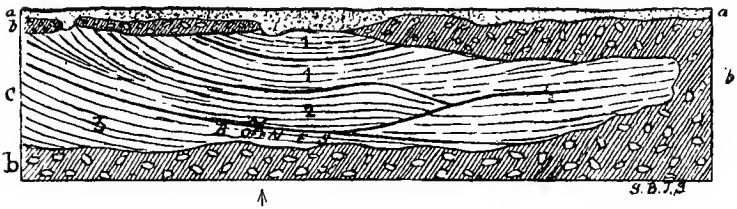
* *Quart. Journ. Geol. Soc.*, vol. xvii., p. 363. (1861.)
† *Phil. Trans.*, vol. cliv., pt. 2, p. 268. (1864.)

FIG. 18.

Section at the Beeches Pit, between Icklingham and West Stow.

(Northern Face.)



× Position at which flint-implement was found, above ⅄. Others have since been got by MR. H. PRIGG, of Bury.

a. Sand and gravel.

b. Boulder Clay, thin above the loam (about 20 inches on the southern side of the pit). Very chalky, with few foreign stones, but with many large flints.

c. Loams, with carbonaceous seams (shown by the dark lines). 1 (upper part) buff. 2 (middle) loess-like, with shells of *Cyclas, Pisidium, Bulimus, Helix* and *Succinea*. 3 (lower) grey and more clayey. Below the lowest black seam, where the word "Bones" is marked in the figure, quantities of splinters of mammalian bones, several teeth and part of a lower jaw were found, and these, according to PROF. HUXLEY, belonged to young individuals of *Bos* or of *Cervus*. The loam immediately below this seam was stained red, by iron-oxide (bog-iron ore).

MR. SKERTCHLY says that "the pit known as the Beeches Pit, from being close to a clump of beech-trees, about half way between Icklingham and West Stow, is about a third of a mile E.S.E. from the brickyard, marked on the map. It was worked for loam and abandoned when the Boulder Clay was found to be too thick to allow it to be profitably worked. The section noted by me was as shown in Fig. 18." He regarded the loam as Glacial; but other observers take it rather to be Post-Glacial, thinking that the mass of Boulder Clay above has fallen over, or has been re-arranged. That below indeed seemed to show signs of re-arrangement. The contents of the loam certainly favour the Post-Glacial view.

The following is also from MR. SKERTCHLY's notes:—

"At the brickyard about a mile E.S.E. of Icklingham All Saints Church, beneath the gravelly soil, dirty loess-like loam is worked to the depth of 15 feet. It dips westward at an angle of about 2°, and in places contains freshwater shells, many fragmentary. *Bulimus* is the most common genus, *Pupa* is frequent [no freshwater genus is named.—W. W.] I have also found seeds of plants. No implements have yet (? 1877) been found; but I picked up a small flake, from a fresh piece of talus, that looked as though it had fallen from the loam. Bones and deer-horns have been found, but were buried up by the workmen."

"The section of the western end of the pit is as follows":—

Gravelly soil, say 2 feet.

Dirty brown loess-like loam, with a few small flints and some thin seams of sand; three bands of race, with a few flints in the uppermost, 5 feet down in the loam, 6 feet 2 inches, and 6 feet 11 inches. Seen to over 10 feet.

"At the eastern end of the pit the following section was seen":—

Gravelly soil, say 2 feet.

Reddish loam, obscurely laminated above, more evenly bedded below, with few shells or flints, 8 feet.

Darker, brown, clayey loam, 2 feet.

Dark grey clay, 3 inches.

Light-grey clay, with black specks, seen to 2 feet.

"On the opposite (eastern) side of the lane is a gravel-pit. A very fine section, 20 feet deep, in these gravels and loams, is open near by." Mr. Bennett adds that "the well at the brickyard is said to have been sunk through 30 feet of loam, to chalk."

The surrounding gravel has been worked westward of the brickyard, and Mr. Bennett has the following note of a pit here:—"Chalky sand, gravel largely made up of chalk pebbles, and seams of loam in places, were dug to the depth of 15 feet. The sand is false-bedded, in places black with carbonaceous matter, and contains broken-up shells (*Gryphœa ?*)." Again, "by the road to the S.W. coarse sub-angular sandy gravel was worked, down to chalk." Dr. Evans records the finding of flint implements here, and adds that "Mammalian remains are scarce, but teeth and portions of tusk of *Elephas primigenius* have been found at Rampart Hill [Field]."*

Below this no River Drift has been mapped on the right side of the Valley of the Lark.

Valley of the Little Ouse.

From Barnham St. Gregory to about a mile below Thetford a strip of Drift borders the marsh, on the left side. At the higher end, about a quarter of a mile north-westward of Barnham Station, was a pit showing a little sand and flints over rubbly chalk. The lower end of this is sand, and nearly three quarters of a mile below where the high road crosses the river, at Thetford, there was a pit in sand with flints. Mr. A. G. Wright tells me that he has two flint implements from the gravel near Barnham.

On the other side there is but a wee patch, until reaching our northern boundary, N.W. of Thetford, where is the beginning of a narrow strip running into the district to the north (Sheet 65). This last small area is of some importance, however, as having yielded many flint implements. Mr. J. W. Flower has thus described it:—"On the right bank of the river a terrace of . . . ferruginous sands, irregularly laminated, and containing layers of flint-gravel, is found resting upon the Chalk. This terrace commences about a quarter of a mile below the town [not so shown on the map]; it extends along the course of the river for about a mile and a half, and is on the average about forty yards distant from the bank, and rises about eight or ten yards above it. The base of the bed, to the extent of four or five feet in thickness, is composed of large nodules of subangular flint, with some chalk-pebbles and calcareous sand; and it is in this coarse gravel, at a spot known as Red Hill, near the second stanch in the river below Thetford, that nearly all the flint implements have been found, usually at from twelve to fifteen feet below the surface, and within a foot or less of the chalk. Some specimens . . . were found in pot-holes in the chalk." Two fine implements are figured, and the occurrence of part of a molar of *Elephas primigenius*, part of a tusk, bones of ox, and the tooth of horse is noticed.† At a later date Mr. Flower adds, "I have found at Thetford a thin seam of fine white sand, with a few land and freshwater shells, lying some feet above the gravel in which the implements occur."‡

In the next year Mr. H. Prigg gave the following section of the beds at Redhill, a name not on the map §:—

Soil; a foot.

Yellow sand, slightly clayey, with ferruginous seams and layers of small flint shingle; 5 to 7 feet.

Slightly rolled and sub-angular flints in an ochreous sandy matrix, with seams of silt and chalky detritus (the implements usually from this); 6 to 9 feet.

A similar matrix, with larger chalky patches, large masses of flint but slightly broken, and some sub-angular flints; 6 to 9 feet.

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* The Ancient Stone Implements . . . of Great Britain, p. 488.

† *Quart. Journ. Geol. Soc.*, vol. xxiii., pp. 46, 47, 49, 50, 53. (1867.)

‡ *Ibid.*, vol. xxv., p. 452. (1869.)

§ *Quart. Journ. Suff. Inst.*, vol. i., no. i., p. 5. (1870.)

In 1872 Dr. Evans noted that implements occur above as well as below the bed of shelly sand noticed by Mr. Flower, gave the following list of shells from one sandy layer:—*Ancylus, Bythinia, Helix, Succinea, Cyclas,* and *Pisidium,* added stag to the mammalia, figured five implements or flakes, and remarked that "a considerable number of flint flakes of various sizes and shapes have been found at Redhill, many of them showing signs of use and wear on their edges, and some being worked to a quadrant of a circle, or more, at the point, so as to make them almost assume the form of scrapers."*

The patch of sandy loam South of Eriswell, the gravel-capping of the hill just east of Eriswell Hall, and of that just north of Lakenheath, now fringe a tributary valley of the Little Ouse.

Valley of the Ouse.

Mr. Skertchly says "between Roslyn Hole and Ely is a mass of gravel lying on Lower Greensand. This is a Post Glacial deposit of very slight extent, but singularly full of mammalian bones. It is not often opened, but when pits are made in it the bones are plentiful enough to excite the emulation of dealers in marine stores, who buy them at the rate of 4*d.* a stone." In the Fenland Memoir *Bos longifrons, Cervus,* and *Equus fossilis* are recorded as found at Ely, probably in this pit.

Flint Implements.

The gravels, &c. that have been described in this chapter are notable for having yielded a great number of these implements, that, clearly having been fashioned by the hand of man, give us our earliest evidence of the existence of our species in England. Whether any of these implements have come from beds older than the Boulder Clay is a question that has given rise to much controversy, into which there is no need now to enter. Mr. Skertchly thinks that the implement-yielding loam of Warren Hill (p. 56) is older than the Boulder Clay, and that at Mildenhall and Culford certainly is so (*see* pp. 51, 55, 56), and the only argument open in these latter cases, against the finding of flint implements in Glacial beds, is to doubt whether the implements were really got from the loam in question.

The various occurrences having already been noticed, in the descriptions of the sections, it now remains only to give some illustrative figures of the local implements, for which we are again indebted to the liberality of Dr. Evans, from whose work they are taken.†

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* The Ancient Stone Implements . . . of Great Britain, pp. 495–499.

† The Ancient Stone Implements . . . of Great Britain, pp. 489–491, 493, 496–499. 1872.

FIG. 19.

Flint Implement, from Rampart Hill, Icklingham.

Rampart Field of the Map. Half size.

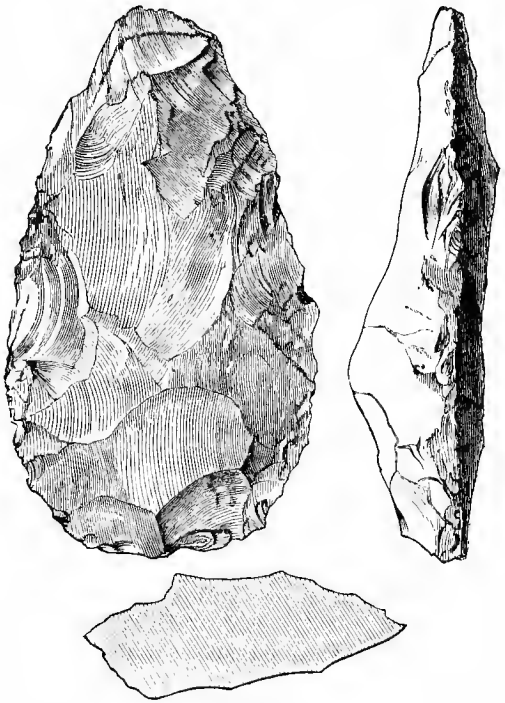


FIG. 20.

Flint Implement, from Ichlingham.

Half size.

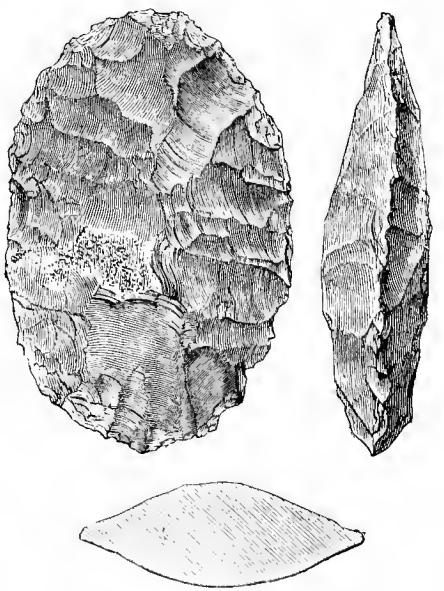


Fig. 19 is from a specimen in Dr. Evans' collection, and he says of it "a portion of the butt presents an almost scraper-like appearance. The angles formed by the facets are slightly worn, and the surface of the flint has been much altered in character, having become nearly white, and quite lustrous. This alteration in structure is almost universal with the Icklingham implements, though in many cases they are ochreous instead of white . . . In many instances the angles are much waterworn."

"The original of" Fig. 20 "is in the Blackmore Museum, and is of dark brown lustrous flint."

Fig. 21 is "from the original in the Blackmore Museum," which "is of dark ochreous flint, with the surface considerably decomposed, and the angles but little worn."

Fig. 21.

Flint Implement, from Icklingham.

Half size.

F 2

FIG. 22.

Flint Implement, from Warren Lodge, Warren Hill, east of Mildenhall.

Half size.

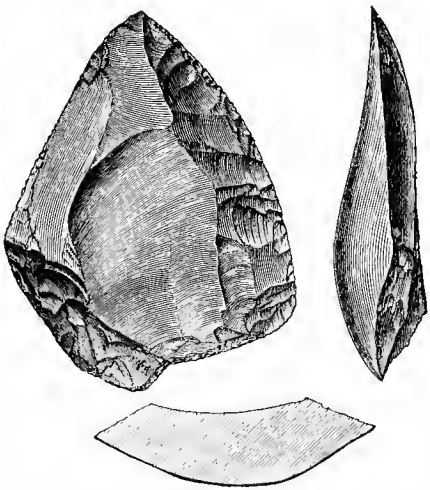
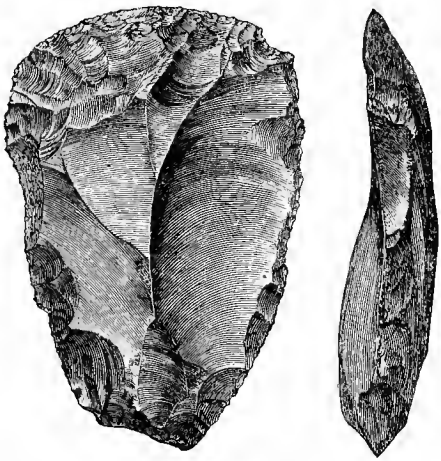


FIG. 23.

Flint Implement, from Warren, Lodge, Warren Hill.

Full size.



In DR. EVANS' work, Figs. 22 and 23 are given as from High Lodge; but in the text this is clearly marked as the equivalent of Warren Lodge, not the High Lodge of Eriswell High Warren, more than two miles north-eastward.

Fig. 22 "has been made from a broad, flat, truncated flake, with a well-marked cone of percussion. The two sides have been carefully trimmed to a curved edge by secondary chipping, and the edge itself has been finished by a subsequent process of finer chipping. . . The workmanship generally is of a finer and neater character than usual on the implements found in the River Gravels."

Fig. 23 is of scraper-like form.

Fig. 24 is from a "fine specimen of a very uncommon form, it being much more acutely pointed than usual. It is stained all over of a deep ochreous colour, and its angles are still sharp. It has been boldly but symmetrically chipped."

FIG. 24.

Flint Implement, from Redhill, Thetford.

Half size.

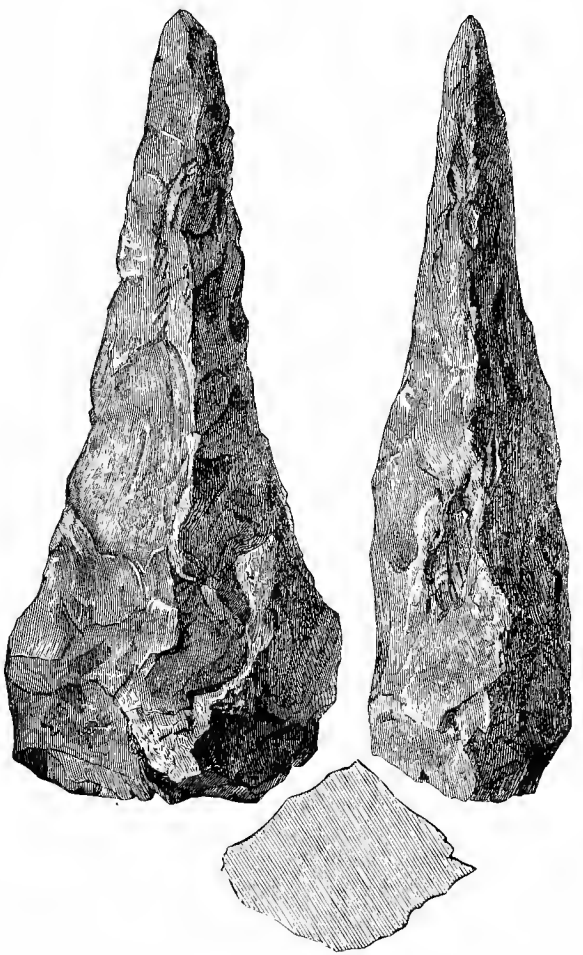
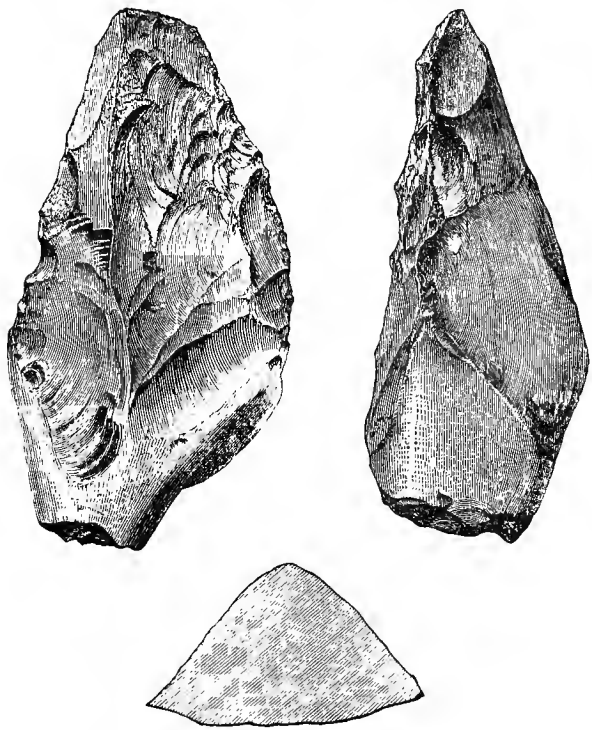


FIG. 25.

Flint Implement, from Redhill, Thetford.

Half size.



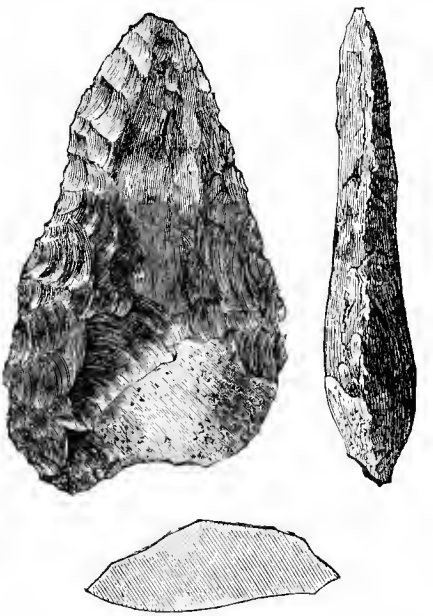
In the specimen shown by Fig. 25, "the greater part of the butt end . . . exhibits the original crust of the nodule of flint . . The point . . has been broken in old times."

"The implement shown in" Fig. 26 "has been formed from a large external flake," which "has been trimmed into shape by chipping along the edges on both faces. . . The surface is, as usual, stained of a rich ochreous brown."

FIG. 26.

Flint Implement, from Redhill, Thetford.

Half size.



Our district has been one of the chief sources of supply, and therefore its flint implements are well represented in various public museums; notably in the Blackmore Museum, Salisbury, where there are specimens from Warren Hill, Icklingham, Thetford and Bury St. Edmunds (just over our southern border), and in the British Museum (Christy Collection). Still more specimens are to be found in private collections, of which three may be mentioned. MR. H. PRIGG, of Babwell Friary, Bury St. Edmunds, has a very large collection of local implements, including many fine specimens, got during a long residence in that town; the well-known collection of DR. EVANS, at Nash Mills, Hemel Hempstead, contains specimens from Warren Hill, Icklingham, Bury St. Edmunds and Thetford; and of late years, MR. A. G. WRIGHT, of Priory Road, Malvern, has got specimens, in fresh ground, at Kennet, and in the neighbourhood.

Various Beds not shown on the Map.

Besides those masses of Drift which can be mapped there are often gravelly and sandy deposits that, from their thinness, inconstancy, or irregularity defy the geological surveyor. In many cases their position is shown only by lettering on the map. Amongst these is some Blown Sand.

Mr. W. Hill has made the following notes of Drift seen on the Mildenhall Railway:—

"As the railway enters the long low cutting west-north-westward of Fordham, from 3 to 5 feet of Drift were seen over the Chalk Marl. So like is the base of this Drift to the Chalk Marl in colour that, where both are weathered, it is difficult to tell where one ends and the other begins, but the occurrence of small angular flints and of rolled pieces of chalk generally give a clue. The white material soon becomes mixed with yellowish-brown sand or sandy gravel, and finally passes into the reddish gravel at the surface. Similar Drift occurs in the shallow cuttings between Isleham and Worlington."

It would seem that this material belongs to the thin unmappable surface-deposits that so often occur irregularly on the Chalk.

The following notes are by Mr. Skertchly:—

"A pit on the high road, by the cross-roads nearly a mile S.S.W. of Wangford Church, showed a thickness of about 2 feet of red sand, with weathered angular flints, and in places peaty, lying unevenly on rubbly chalk, with a few scattered flints, open for 5 feet."

"A pit on the eastern side of Elvedon Warren Plantation (W.N.W. of Elvedon) showed, in 1875, about 5 feet of sand with flints, over Boulder Clay, of the usual character, to a depth of 12 feet. The junction was very irregular, seams and lumps of the sand lying in the upper part of the clay."

"In another pit about 200 yards southward, by the side of the road, the Chalk seemed to be about 15 feet from the surface of the ground, and all the overlying matter to be sand. The section, however, was very obscure, being grass-grown and probably deceptive, for a third pit, a few yards to the south, showed a like section to the first, and others were also seen in two pits nearer the high road, close to Elvedon."

"In a pit north of Elvedon Lodge a thickness of at least 8 feet of very clean sand, with comparatively few flints, was seen (in 1875), over Boulder Clay."

"Some pits, dug for gravel, on the slope of the hill between The Elms Plantation (at the southern end of Brandon Park) and May Day Farm (on the road to the east) were only about 4 feet deep, in 1875, and in sand full of angular black flints, retaining their cherty coating on the old surfaces; chalk-pebbles were abundant, and weathered flints and sandstone-pebbles occurred sparingly."

"In the low tract west and north-west of Eriswell the Chalk is hidden by a sheet of sand, often apparently thick, but thinning away gradually to the south. Between Beck Row (N.W. of Mildenhall) and Eriswell the material is blown sand, and all the flints and other pebbles are beautifully polished, just as takes place on the deserts of Africa. The appearance is very striking. From this place I obtained a fine flint core. The loose sand forms an undulating surface, in the hollows of which peat has formed, and at many places the sand has blown over beds of peat and thus seems to be of newer date, but there is no doubt it is mere wind-drift."

"From Northcote [? Northcourt], northward of Wangford, along the high road southward, there is a wide sand-covered plain, on which the sand rises in hummocks to 8 feet. The Chalk nowhere appears at the surface. The shading of the map is wrong, there being no such hills as are engraved. The sand [speaking of level ground by Northcourt Lodge] is blown sand and the stones therein are polished. When the wind is S.W. the air is full of sand, blown from Lakenheath Hills."

At Thetford Cemetery, S.W. of the town, I was told that chalk was not touched in the graves; but that sand and gravelly earths alone were found.

Treating partly of the tract just to the north (in Sheet 65) an old writer made the following interesting "Curious and exact Relation of a Sand-floud, which hath lately overwhelmed a great tract of Land in County of Suffolk."

"These wonderful sands, which although they . . . have not yet exceeded one *Century*, since they first broke prison, I could not without some difficulty trace to their Original. But I now find it to be a Warren in *Lakenheath* . . . where some great Sand-hills (whereof there is still a remainder) having the *Superficies*. . . of the ground . . . broken by the impetuous *South-west* winds, blew upon some of the adjacent grounds; which being much of the same nature, & having nothing but a thin crust of barren earth to secure its good behaviour, was soon rotted & dissolved by the other Sand, & thereby easily fitted to increase the Mass, & to bear it company in this strange progress."

"At the first Eruption thereof . . . the whole Magazin of Sand could not cover above 8 or 10 acres of ground, which increased into 1000 acres, before the sand had travailed 4 miles from its first aboad. Indeed it met with this advantage, that till it came into this Town [Downham], all the ground, it past over, was almost of as mutinous a nature as itself, & wanted nothing but such a Companion to set it free." . .

"Tis between 30 & 40 years, since it first reacht the bounds of this Town . . But that Valley being once past, it went above a mile (*up-hill*) in two months time, & over-ran 200 acres . . the same year." . .

"The branch of the River Ouse upon which we border (. . Thetford or Brandon River [Little Ouse] . .) for 3 miles together so filled with Sand, that now a Vessel with two load weight passeth with as much difficulty as before with 10." *

Mr. Bennett remarks that "the tract within which this sandy covering occurs is also that wherein the Boulder Clay is thin, patchy, and containing much sand; so that a good deal of the surface-sand may have resulted from the weathering of the Boulder Clay in a dry treeless area, where sun and air would have a powerful disintegrating effect on the thin, sandy clay; whilst over these bare plains the winds would soon distribute a more or less general mantle of sand."

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* T. Wright. *Phil. Trans.*, vol. iii., no. 37, pp. 722–4. (1668.)

CHAPTER VIII. ALLUVIUM.

THE latest deposit of our present streams, forming the broad fens through which they flow, or the narrow marshes at the bottom of their valleys, consists of marsh-clay, or silt, often with layers of peat, and sometimes with shell-marl.

As our district includes the southern end of the great Fenland flat, this chapter will consist almost wholly of a description of the beds of that tract, there being little to be said of the Alluvium of the tributary-valleys.

THE FENS, INCLUDING THE VALLEYS OF THE OUSE AND OF THE CAM.

At their southern end the Fens sweep round the Ely district, along the valley of the Ouse, and some way up the valley of the Cam; whilst eastward of Ely they reach to the valley of the Lark, with the Soham peninsula jutting out and barely separated from some islands on the north (Barraway, Stuntney, &c.), besides being only five eighths of a mile distant from the Isle of Ely itself at Thetford.

The description of this peculiar tract is taken from the Fenland Memoir, by MR. SKERTCHLY (to p. 101), with such slight alterations as were needful.

The Peat.

Roughly speaking the peat is thicker in the south than in the north. The greatest thickness attained by the peat, so far as I have ascertained, is 18 feet, in the parish of Earith, inside the Wash bank, 648 feet north of the bridge at Mr. B. Vipon's house. A like thickness was pierced in the parish of Warboys, 780 yards from the Plow Puttock Drove. In both these places the peat rests on gravel, the marine silts and clays being entirely wanting. It seems, therefore, that after the deposition of the gravel no return of marine conditions took place in these places, and the peat represents the different peat-beds as well as the intercalated marine beds of other parts. Indeed, from toward the end of the gravel-period climatal conditions became favourable to the growth of peat, which began to grow whenever physical conditions permitted. The gradual silting-up of the great bay which now forms the Fenland, and the intermittent irruptions of the sea have resulted in the production of many local deposits of peat which are now buried entirely. What peat-beds show is the prevalence of land, or rather of stagnant

fresh-water conditions, and the thickness of the deposits affords a rough measure of the time those conditions lasted; the thicker the bed the longer being the period. But here we must guard against error by limiting the comparison to neighbouring areas, for it would clearly be wrong to estimate the length of time required to form a foot of peat in the neighbourhood of Croyland as equivalent to the time required for such a growth in the vicinity of Ely. In the former case the peat is younger in date and did not form under such favourable circumstances, and consequently grew slower than in the latter. Again the lower beds are compressed by the weight of the superincumbent beds, and the upper bed is reduced in thickness by drainage and cultivation, so that the approximations are but crude.

The upper part of the peat has weathered to a black or deep brown material, showing no trace of vegetable structure, and quickly crumbling into cuboidal pieces.

Where the peat is comparatively thick, as in the Isle of Ely, the weathering is seldom apparent to a greater depth than a foot. Beneath this layer the peat is fibrous, more or less compact, showing vegetable tissues in the shape of fragments of aquatic plants, especially reeds, rushes, and rootlets of willows and of sallows. In colour it varies from black, through deep-brown to russet, and in consistency is soft enough to allow the finger to be pushed into it. It is so elastic that the ground quivers when stamped upon, and a horseman galloping down a peat-road causes it to shake bodily. When a spring rises through it the peat absorbs a quantity of water and swells into a boss, which yields like a sponge when trodden upon.

The lowest portions of the peat are seldom used as fuel, being for the most part composed of moss (*Hypnum*) which forms a very light, open-textured, golden-yellow material, in which the moss appears but little altered.

The following description of the peat at the Turbary, north-west of Coveney, near Ely, may be taken as a sample of the peat-sections in the Fenland. The peat is dug to a depth of four feet, and the fresh section appears quite black, with the exception of the upper 10 or 12 inches, which are of a dark chocolate-brown. This upper brown portion consists of an amorphous mass of roots, rushes, &c., with elytra of marsh and of aquatic beetles, and remains of other insects, and it differs from the underlying material in not being bedded. The lower three feet are composed of black turf, in which the vegetable structure is obscure. It contains roots of reeds, flags, rushes, sallows, &c., and forms the best fuel. At the bottom the peat is almost exclusively composed of moss (*Hypnum*), and dries a yellow colour, having much the appearance of golden bird's eye tobacco, but the colour is not distinct until the peat is dry. The moss-tissue is perfectly preserved, and friable when dry. These lower parts of the peat separate easily in the layers of bedding. A white efflorescence appears upon the peat when dry, which is

probably sulphate of lime, since small crystals of selenite are not unfrequently to be observed in it.

My friend, MR. A. GRUGEON, has kindly examined a specimen of peat from Coveney, which showed both the dark and light varieties, and he reports thereon as follows:—

"There appear to be numerous rushes without any of the interior cells remaining, although plenty of large loose cells float out from the mass. They do not, however, possess the stellate form of rush-cells, which may be owing to their liberation from their cylindrical confinement, an opinion I am inclined to entertain from their large size. Numerous threads of *Conferva* occur, and *Hydrodyction utricularis* abounds. Leaves, calyptra, and seta of moss of at least two species occur, and one rough surfaced seta like *Hypnum acetabulum*, but the habitat is not that of this plant. Nuclei of *Chara* occur sparingly, and two kinds of diatoms, one a most beautiful form. Spore-cases of *Lastrea* are plentiful, and as perfect as when first gathered. A few bundles of spiral vessels attest the presence of phanerogamous plants, but the species are not determinable."

"The brown peat is all moss of one kind, and appears to be a strong-growing form of *Hypnum fluitans*."

"Throughout, the remains of Coleoptera and Hymenoptera are found. This is only the result of the examination of a piece of peat the size of a hazel-nut."

It is remarkable that the true bog-moss, *Sphagnum*, does not occur in the Fens, either recent, or extinct in the peat. Its place is taken by the *Hypnum* above-described.

At present there is no evidence of the formation of peat under natural conditions in the Fenland, with the solitary exception of a slight moory deposit near Eriswell and Mildenhall, where, in a dank valley, the sedges and rushes thrive luxuriously, their matted roots decaying into a fibrous mass, black when sodden with water, but light-brown when dry, which is dug in slabs and used for fencing.

The following is a description of the buried forests of the Fenland peat, referring of course to parts beyond as well as to our district:—

The trees composing the forest were oak, elm, birch, yew, willow, and sallow, of which the oak was by far the most numerous. The trees in some cases attained colossal dimensions, but as a rule they are not remarkable for size. The roots are in many cases in place.

The timber is in all cases stained, through lying in the peat, but the colour varies from almost black to grey. The wood of the oaks is often sound enough to be available for rough work. It is used for fencing, gates, and other purposes, but it will not do for posts, as it soon rots when in the ground. The greater portion, however, is fit for nothing but fuel, and it is usual to

see stacks of gnarled roots and great logs of timber piled near the cottages, showing by their black colour whence they came. The birch trees are rotten, but their papery bark preserves its silvery lustre, like its congeners in North America, after the wood has crumbled away.

Most of the trees are mere trunks, broken off above the bole and at the fork, so that to the length observed we may generally add a quarter to obtain the original height of the tree.

The preservative character of the peat is shown by the presence of bark upon the *under* side of the trunks, where the tree was in contact with the peat, and between the buttresses at the base of the trunk. The bark has evidently wasted from the upper surface in consequence of decay having set in before the tree was covered up with peat.

The oaks are in all cases stained black; the yews retain their peculiar brown, and the timber of the firs is as white and sound as if from living trees; the odour of turpentine is distinctly perceptible in cutting the wood.

(The questions of the origin and of the cause of the destruction of the forests are general to the whole Fenland, and the reader is therefore referred to the Memoir thereon for their discussion.)

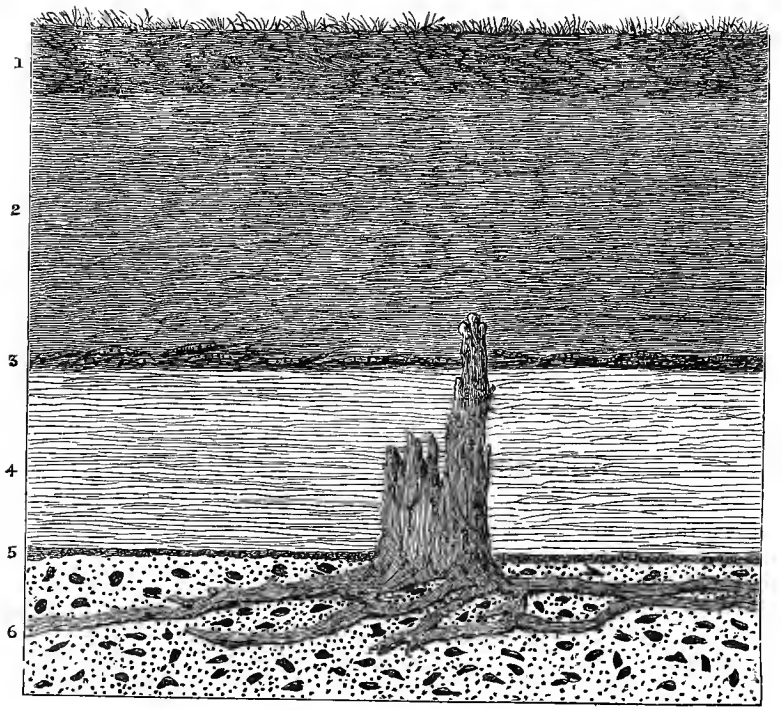
In the neighbourhood of Ely a succession of forests can be clearly made out, as was pointed out to me by MESSRS. MARSHALL and MARSHALL FISHER of that city; both diligent observers of fenland-phenomena, who having lived in the district for many years have enjoyed great opportunities for observing the position of the trees.

The former gentleman assured me that the yews (*Taxus baccata*) are invariably found in the lowest positions, rooted in fact in the sand, which is found at a depth of from 10 to 12 feet. The sketch (fig. 27) is from a drawing by him made on the spot, and shows, moreover, the peculiar manner in which the roots spread out instead of sending down a tap-root deep into the ground. This feature is common to the oaks and firs in the district, and seems to show that the trees could find nourishment only in these particular beds.

In December 1874, in company with MESSRS. MARSHALL and FISHER, I visited Wood Fen, between the highlands of Ely and Littleport (partly just beyond our district), and, with the assistance of the workmen, we obtained highly satisfactory evidence of the succession of forests. We carefully examined the fen from the Ely side to its centre, and at right angles also; and, wherever it seemed necessary, had the trees dug out or the fen-beds bottomed.

The peat at first lies directly upon the Kimeridge Clay, upon which a few stones are scattered, giving a somewhat boulder-clay-like appearance to the upper foot or so. The peat gradually thickens from a foot to eight feet, and at about three quarters of a mile west of the high road fen-clay, about two feet thick,

FIG. 27. *Marshall's Yew, Wood Fen.*



1, 2. Peat.
3. Peat, full of twigs.
4. Clay.
5. Peat, with twigs.
6. Gravel.

comes on, and is underlain by 10 inches of the fetid peat known as "bear's muck."

The general result of our investigation may be thus stated. At the base of the peat, with the roots bedded in the Kimeridge Clay, a forest of oaks is found. The trunks are broken off about three feet from the roots, and generally lie very nearly N. and S., but with exceptions. Some of these trees are of fine proportions, three feet in diameter, quite straight, and very seldom forked. Under their roots the Kimeridge Clay is often preserved, as if the general level had been reduced by erosion before the formation of the peat (see Fig. 28). The workmen are of opinion that the trees in falling have prised up the clay, but in most instances the trees have been broken off not overthrown. It was quite striking to see clay thrown up on to the bank by the men who were deepening the dyke, whenever an oak was found. As the clay approached the surface the oaks, of course, came up with it, and on the margins of the fen the stumps were within two feet of the top instead of full eight feet down. We will call this forest No. 1.

At an average height of two feet above forest No. 1 the remains of another are found, consisting of oaks and yews, the

former often rivalling their more ancient brethren in magnitude; the latter generally but two or three inches, though occasionally a foot, in diameter. That forest No. 1 had succumbed to deadly influences before the growth of the trees in question is proved by the newer trees being sometimes seated upon the broken stumps, or astride the prostrate trunks, of the older trees; indeed the trees in all the forests to be noticed seem to possess a partiality for such strange situations. MR. MARSHALL observed that in Switzerland he had sometimes seen as many as four young firs astride a fallen trunk. Fig. 28 represents a yew upon the stump of an oak, and also the underlying clay preserved beneath the latter, as before mentioned.

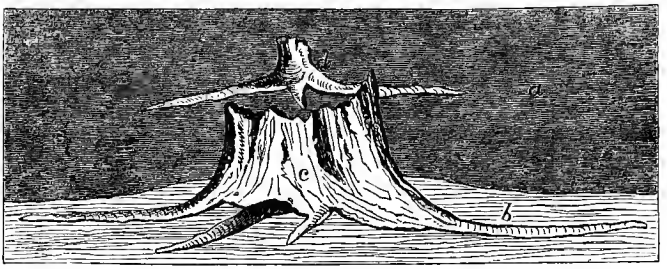
The trees do not lie so regularly as in the lower forest, and many trunks lie across the older ones at right angles, or from E. to W. We will distinguish this forest as No. 2.

Three feet above forest No. 2 lie the remains of another, in which the trees are all firs, probably *Pinus sylvestris* (Scotch fir), but, as we could not find cones, the species is doubtful. Some of these firs must have been of colossal dimensions; one was quite $3\frac{1}{2}$ feet in diameter at the base of the trunk. Similar undoubted evidence of the relative age of this forest is to be obtained, and in Fig. 29 an uprooted fir is shown that grew over an oak and sent a great root right underneath it, which has been twisted in the fall, but has not given way. This forest will be distinguished as No. 3.

Immediately above it, and (now) close to the surface, is a yet newer line of firs, exclusively confined to the Ely side of the fen. The trees are all small, and in a dyke alongside a small spinney, four are seen astride of the older ones. Fig. 30 represents one of these, the cut end of the lower tree having been severed in making the dyke. This we shall call forest No. 4.

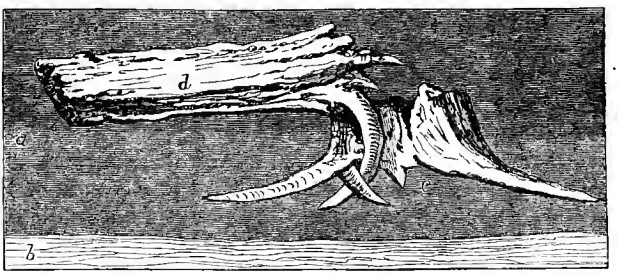
Many remains of sallows, of willows, and of alders are found in the peat close to the surface, and may be termed forest No. 5, but it is probably of historic date, and the trees are of the same species as those now growing in the fen, which are very probably their immediate descendants.

FIG. 28. *Yew growing upon Oak, Wood Fen.*



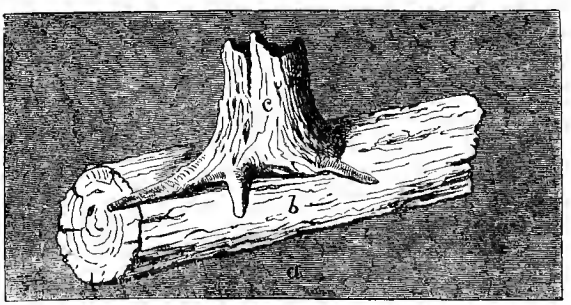
a. Peat, 6 feet. *b*. Kimeridge Clay. *c*. Oak. *d*. Yew.

FIG. 29. *Fir clasping Oak, Wood Fen, near the old Blue Boar.*



a. Peat, 5 feet. *b*. Kimeridge Clay. *c*. Oak. *d*. Fir.

FIG. 30. *Fir astride Fir, Wood Fen.*



a. Peat. *b*. Fir. *c*. Fir.

It is therefore clear that in the Isle of Ely the following succession of forests is determinable. The depths given are maxima, for, as the fen-beds thin toward the highlands, the forests become crowded together.

5. Sallow (*Salix cinerea*), in peat at 1 foot.
   Willow (*Salix*, several sp.), in peat at 1 foot.
   Alder (*Alnus glutinosa*), in peat at 1 foot.
4. Fir (*Pinus sylvestris?*), in peat at 2 feet.
3. Fir, in peat at 3 feet.
2. Yew (*Taxus baccata*), in peat at 6 feet.
   Oak (*Quercus robur*), in peat at 6 feet.
1. Oak, in clay at 8 to 10 feet.
   Yew, neighbourhood of Hilgay (Sheet 65), in sand at 8 to 10 feet.
   It is to be noticed that the oak and yew do not occur together in this bed as in 2, but occupy separate areas dependent on the nature of the subsoil.

The only species in the above table not now living in the district is the fir, if the determination of the species be correct.

Roots of trees may also be well seen in place at Coveney and Downham, West Fen.

The almost invariable direction of the fallen trees in the peat of Fenland is from N.E. to S.W., the heads being to the N.E.; but a remarkable exception occurs in the immediate neighbourhood of the Isle of Ely. Thus in West Fen, near Downham, I found four trees, oaks and elms, lying within short distances of each other, whose heads bore N.E., N.W., N.E., and E. In the fen near Wood House, Chetisham, two trees, close together, bore respectively N.E. and E. by S. In Middle Fen, between Stuntney and Quaney, two trees bore N.E. and N.N.E. These examples prove that in this locality the direction of the trees is not nearly so constant as in the open fen, but the prevailing direction is still north-easterly.

The direction of the trunks is often very clear in consequence of their intersecting the smaller dykes which bound the grounds. In such cases it is usual to leave the trunk so as to form a natural bridge across the dyke. Examples of this are abundant in West Fen.

The trees now growing along the dykes and droves of Fenland slope towards the north-east, because the prevalent wind is from the south-west; but among the islands of the Isle of Ely this unity of trend is not so noticeable, the reason plainly being that the winds eddy among the islands, and thus lose to some extent their normal direction.

The analogy between the lie of the buried trunks and the trend of the living trees is perfect; *the trees of the buried forest lie in the same directions as the living trees would take if free to fall.*

Large oaks lying in all directions are found in the peat in Soham Mere. One was said to be 2½ feet in diameter, and

another (found on Angle Farm) was described as being 90 feet long and nearly 4 feet in diameter.

N.W. of Ely we find in West Fen numbers of trees (oaks, elms and willows) averaging about 20 feet in length, and quite straight. There seems to be no general rule as to the point at which they have broken off, some being severed just above the bole, others torn off by the roots. One tree, a birch, was charred at the base.

The Shell-Marl.

Stretham and Soham Meres lie within the Bedford Level and in the peat-district, and upon their sites this deposit is found.

Moreover in the South Level a deposit of shell-marl is very generally found from a foot to two feet below the peat-surface. It is white, friable and full of fresh-water shells, of which the species obtained are named in the list on pp. 101, 102.

It can be traced in dyke-sections from Burwell Fen by Stretham Mere, Barraway, Quaney, and Burnt Fen, to near Lakenheath. It is not absolutely continuous, but appears, as might have been anticipated, to have formed in shallow meres or lakes. Its greatest development is in Sedge Fen, south of the railway, near the Cross Bank. It is there dug for manure, and known as "chalk marl," and being got in trenches, some of which are at right angles to others, the features of the deposit can be well studied. The greatest thickness is $3\frac{1}{4}$ feet, but for more than two square miles it is not less than two feet. The pure white of the marl and the dark colour of the overlying and underlying deposits make the sections very striking. Here and there a layer of peaty material marks a cessation of the formation, and the perfect evenness of these layers attests how quietly the marl was formed. Not a stone or patch of clay or other foreign matter can be found, and the fresh-water shells seem to be pretty persistent throughout, whilst here and there perfect nests of *Limnæa* and *Bythinia* are discovered. The mass is jointed so as to form large lozenge-shaped masses, and the main joints are very regular.

The roots of *Chara* can be seen in it, and the seeds obtained by careful examination. Indeed, I have no hesitation in attributing the formation of the shell-marl to the decay of *Chara* of various species. These plants are still living in the neighbouring dykes, where, so far as my observation goes, they form dense masses to the exclusion of other plants. Only one species (*C. flexilis*) is perennial, the other 15 are all annual. The axes of two species, *C. vulgaris* and *C. hispida*, are encrusted with carbonate of lime. The plants do not, I believe, live, or at any rate do not thrive, in muddy water, and on dying decompose with a fetid odour which is regarded as one of the sources of malaria. The carbonate of lime forms a deposit at the bottom of the water. One season's deposit is usually only a white stain, but under exceptional circumstances an appreciable thickness is formed.

For example, in the ditches in Burwell Fen, where the Charas thrive luxuriantly, a deposit of from two to four inches was formed in the summer of 1874 on the evaporation of the water during the drought.

Applying these facts to the sections in Sedge Fen, we see that the peaty layers mark breaks in the growth of the *Chara*, during which the peat-forming plants grew, but not in force. The most feasible explanation of the deposit seems to be that the marl formed in shallow meres, when the aquatic plants were almost entirely routed by the great luxuriance of the *Chara;* that occasionally, in very dry seasons, the water dried up, and a covering of sedge and of other plants grew upon the sites, and, decaying, formed the peaty layers described. That the water was completely evaporated seems proved by the fact that the layers in question are too slight to have been formed of moss (*Hypnum*). With succeeding rains *Chara* again throve, and so the deposit went on year by year, the plants forming a paradise of food to the fresh-water molluscs, until the thickness of over three feet of pure white marl was produced.

We may conclude that for shell-marl to have been deposited the following conditions must have held:—

1. The water must have been charged with more than an ordinary amount of calcium-carbonate.
2. The water must have been almost entirely free from mud.
3. Some cause must have favoured the deposition of the carbonate.
4. The water was unfavourable for the growth of peat, though molluscs, fish, and the ordinary aquatic plants throve in it.

The calcium carbonate might be derived from the Chalk, the Cam being the chief lime-bearing stream.

Sections.

The following sections, taken from Mr. Skertchly's Fenland Memoir and from his notes, are arranged from west to east and from south to north, and the figures stand for feet:—

Haddenham Causeway (the high road), 1874.

4 feet of peat, underlain by very fine white sand, with small flint and other pebbles, at the bottom of the dyke.

Witcham. Road from Wardoe to Witcham Gravel.

[Alluvium]	Peat	½
	Sand, white and yellow	2 to 4
Kimeridge Clay		2

The sand passes vertically and laterally into a fine gravel on the one hand, and into a white sandy clay on the other. Under one of these forms it is visible on the whole edge of the fen nearly as far as Mepal, as well as under the peat.

Witcham. Wardoe Hill. Western side.

[Alluvium]	Peat, much decomposed	0 to 1
	Sand, mixed with yellow and red clay	0 to 1½
Kimeridge Clay		seen to 4

Grunty Fen. Southern side.

Peat - - -	traces
Clay, soft, with a few flints	- 2½
Kimeridge Clay - -	seen to 2

Grunty Fen. North of Grunty Fen House.

[Alluvium]	Peat - - -	traces
	Sand, white and brown	- 1
Clay, with gravelly seams	-	- 3
Kimeridge Clay, with septaria	-	seen to 3

Witchford. Grunty Fen Drain.

[Alluvium]	Peaty soil - - -	⅓ to ½	
	Sand, white and drab	- 1	
Forms of the Boulder Clay	Clayey sand and gravel, with many chalk-stones - -	1 to 4	say 5½
	Clay, with sandy seams -	1 to 4	
Kimeridge Clay - - - - -			

Lammas Ground, N. of Upware. 1873.

The beds over the peat contain many fresh-water shells, among which fine specimens of *Planorbis corneus* were abundant. A dyke, near the river about three quarters of a mile northward of the Upware Inn, showed 2 feet of peat, thinly covered with alluvial earth, over clay weathering yellow, which may be Gault, seen to 4 feet.

Soham Mere. General Section.

[Alluvium]	Marl - -	1 to 3
	Peat, with oaks	2
Gault.		

Stuntney. Crooked Drain near Norney.

[Alluvium]	Peat -	11
	Clay (fen)	3
Kimeridge Clay.		

Waterden Fen, N.E. of Ely.

[Alluvium]	Peat - - -	½
	Fen clay, with sandy veins -	4

Chetisham. Pit at the 70 milestone between Littleport and Ely.

[Alluvium]	Peat - -	1½
	Sandy loam -	0 to 1½
Kimeridge Clay - -		16
"Stone floor" (septaria-bed)		1¼

Soham. Near Castle's Farm, northward of the Village.

[Alluvium]	Peat - - - -	1
	Sand (ochreous) and clay -	- 4
	Peat - - -	- 1
Clay (Gault?) - - - -		seen to 1

Wood Fen.

[Alluvium]	Peat, with sallows, firs, and oaks -	- 5
	Clay, fen - - - -	- 3
	Mass of decayed roots and clay -	0 to 3
Kimeridge Clay.		

Burnt Fen near Cross Bank.

[Alluvium]	Peat	1
	Shell-marl	3
	Peat	8
	Clay, fen - pierced to	3

S.B.J.S.

At the southern end of the shallow railway-cutting at Soham Cotes there is brown, generally clayey, sand, part of which contains, at the bottom, small white specks, like chalk-grains, and bits of shells (? an *Ostrea* and a *Cardium*). The cutting changes almost suddenly northward, when there is clay (? Gault). I could not make out whether the sand went over or under the clay, in which latter were many phosphatic nodules and *Belemnites*, but in parts it had a reconstructed look.

At the northern part of the cutting alluvial clay, much like Gault, but with many shells of recent species (*Limnæa*, *Planorbis*, &c.) comes on above the other clay, to a thickness of two feet, and slopes down with the slope of the ground.

Of Soham Mere Mr. Woodward noted, in 1880, that "the boundary is indefinite. East of Broadpiece and between Tilehouse and Middle Farm the alluvial margin is on the slope; for I saw 2 to 3 feet of silt with fresh-water shells (*see* following list) above the bluish Gault clay, with *Belemnites minimus*, &c."

Fossils.

Vertebraia.

The following occurrences of human remains were noted by Mr. Skertchly (in the Fenland Memoir):—Two lower jaw-bones and portions of four skulls were dug up, in 1818, about three miles south of Chatteris, in the bed of the West Water, embedded in dark brown peat, but nothing more is known of them. Mr. Marshall, of Ely, has in his possession a skull found in the fens near that place, which was exhibited at the Anthropological Society in 1874, but was pronounced to be comparatively modern.

In the Wisbech Museum Mr. E. T. Newton noted the following:—
Castor europæus, Sutton Fen.
Cervus elaphus, Soham Fen, Wistow Fen (Hunts.), and near Ely.

In the following list of shells L. = from the shell-marl of the South Level, by Mr. Skertchly. M. = from the alluvium of Soham Mere, collected by Mr. H. B. Woodward and determined by Mr. C. Reid.

Gasteropoda.

Bulla ? - - -	L.	—
Bythinia tentaculata, *Linn.*	L.	M.
Limnæa auricularia, *Linn.* -	L.	M.
—— palustris, *Müll.* -	—	M.
—— peregra, *Müll.* -	L.	—
—— stagnalis, *Linn.* -	L.	—
Paludina contecta, *Millett*	—	—
Planorbis carinatus, *Müll.* -	—	M.
—— complanatus, *Linn.*	L.	M.
—— corneus, *Linn.*-	—	M.
—— spirorbis, *Linn.* -	L.	—
Succinea elegans, *Risso* -	—	M.
—— putris, *Linn.* -	L.	—
Valvata cristata, *Müll.* -	—	M.
—— piscinalis, *Müll.* -	L.	M.

Lamellibranchiata.

Pisidium amnicum, *Müll.*	L.	M.
—— nitidum, *Jenyns*	—	M.
Sphærium corneum, *Linn.*	L.	M.

In the Wisbech Museum there are nuts and branches of hazel from Thorney, and shells of *Cardium edule* were found just above them: also black oak from Chatteris Fen.

Tributary Valleys.

Of the Alluvium up the valleys, inland from the Fens, there is very little to be said, sections being of rare occurrence. The area taken up is generally well-marked, from the flatness and dampness of the ground, which sometimes is in striking contrast to the rising slopes of the valley-flanks.

Along the northern part of the railway-cutting westward of Biggen Cottage and north of Landwade, there are, in the grey chalk, some gentle shallow hollows of black peaty earth, with land and freshwater shells. These patches, being above the marsh-level, may be the result of springs from the Chalk.

Where the same railway crosses the marsh in the valley to the east, W.S.W. of Snailwell, the ditches are in peaty earth, with gravel and sand coming up in knobs and forming slight ridges in the alluvial flat.

In the small patch of Alluvium along the valley eastward of the Kennett, the stream sank by the road 1¼ miles south of Herringswell Church, in April 1879. The sinking is marked nearly a mile lower on the map.

There is a strip of Alluvium, mostly narrow, along the whole course of the Lark. At Barton Mills, about a mile above Mildenhall, a trial-boring, for the foundations of the bridge, passed through 17 feet of black sand and clay, to the Chalk, according to information from Mr. G. Hook, of Soham, who made it.

CHAPTER IX. ECONOMIC GEOLOGY.

As regards mineral wealth the South of England is anything but rich; but there is a certain mineral industry confined to that part of the kingdom, namely, the getting of coprolites, or nodules of phosphate of lime, for the manufacture of artificial manure; and our district affords, or has afforded, an example of this work, both as regards the nodules that sometimes occur to a workable extent in the Lower Greensand, and the richer ones that form a layer at the base of the Chalk, which is workable throughout a much more continuous course. Nowhere else indeed have these two beds been worked so near together, for they have both been dug in one parish, that of Wicken.

The Fenland is the chief seat of another peculiar industry, the digging of peat for fuel, and the southern part of that great tract (with which alone we are now concerned) has yielded much in this way.

Beyond this our district shares in the general industries connected with building, and in work for underground water-supply; whilst the various gravels supply materials for roads.

Our district is also of interest as forming part of a small tract, around Brandon (just to the north), where a very ancient industry has survived to our own times, for MR. SKERTCHLY has shown that the mining of flints from the Chalk, for the manufacture of implements, has been continuous around Brandon, from Neolithic times, and "that the flint-knappers are the direct descendants of the old workers in stone." Probably too this range may be extended backward to Palæolithic times, for, as MR. SKERTCHLY says, one "cannot but think that the manufacture of flint implements for various purposes has gone on without any, or [with] but slight, interruptions from the earliest times."* For a full account of this remarkable survival of an industry of prehistoric origin the reader is referred to the Memoir quoted.

COPROLITES.

The phosphatic nodules of the Lower Greensand have been worked at Stretham, from Stretham Ferry Bridge, on the south, north-eastward to within a mile of Thetford, and on either side of the low Upware ridge (*see* pp. 20–28). They are mostly small, and many are phosphatised casts of derived fossils.

The nodules and their associated pebbles are separated from the sand by sifting, and the nodules are then separated from the pebbles by hand-picking. In 1880 MR. H. B. WOODWARD noted

* Memoirs of the Geological Survey. . . . On the Manufacture of Gun-flints, the Methods of Excavating for Flint, the Age of Palæolithic Man, and the Connexion between Neolithic Art and the Gun-flint Trade, 1879, pp. v, 39, 69.

that at the working north-eastward of Spinney Abbey, north-west of Wicken, "60 barrow-loads of the gravel yielded about 3 cwt. of phosphatic nodules, which were picked out, after washing."

An analysis quoted by PROF. BONNEY, and referred to by MR. W. KEEPING, is of nodules from Sandy (Bedfordshire) and not from Upware, as seems to have been thought.*

The following analysis of nodules from Stretham was given to Mr. Jukes-Browne, by MR. H. SPARROW, of Cambridge:—

Moisture and organic matter - - -	4·02
Phosphoric acid (equal to $Ca_3 P_2 O_8$, 45·45)	20·82
Lime - - - - -	33·18
Peroxide of iron - - - -	10·31
Carbonic oxide (equal to $Ca CO_3$, 9·34) -	4·1
Magnesia, fluorine, alumina, &c. -	7·02
Insoluble siliceous matter - - -	20·55
	100

The more valuable layer at the base of the Chalk Marl, known as the Cambridge coprolite-bed, has been worked under the thin alluvium of Burwell Fen, where the workings indeed gave the evidence for drawing the boundary-line of the Chalk; and also where the ground rises up from the Fen, at Wicken, and thence north-eastward to Soham. Beyond the last place it is again hidden for many miles under the broad fens, and has been nowhere worked. In Norfolk, where the Chalk again emerges from the fens, the nodules are so few that the bed is unworkable. The Wicken and Soham sections are described on pp. 36, 37.

For a full description of this bed, of its included erratic stones, of the nature and origin of the nodules, of the fossils, and of the method of working, the reader is referred to the Cambridge Memoir (pp. 24–31, 126, 127, 132, 144, 148–154); it is enough to note here that the nodules are chiefly derived from the Gault.

The following analyses of phosphatic nodules from the district and from that to the south may be useful.

In 1876 MR. W. C. REID remarked of Cambridge coprolites that "Either from the exhaustion of the better sorts or from imperfect washing the quality has lately somewhat deteriorated. . . . The following tests were made before this deterioration"†:—

——	1.	2.	3.	4.	5.
Tribasic phosphate of lime -	60·87	58·52	27·12	54·89	57·09
Carbonate of lime -	18·25	12·47	11·66	15·13	13·27
Oxide of iron and alumina -	5·3	3·49	4·44	3·82	3·24
Fluoride of calcium - -	1·8	2·2	3·	4·	4·33
Insoluble siliceous matter - -	6·5	6·04	6·22	8·64	6·93

In the third column of figures it seems that 27 is a misprint for 57.

* Cambridgeshire Geology, p. 25, and the Fossils of Upware, p. 10.

† *Chem. News*, vol. xxxiv., p. 49. (1876.)

He then gives the following analysis of Wicken phosphates, but whether from the bed at the base of the Chalk or from that in the Lower Greensand is not said; though, from the comparatively small amount of phosphate and the quantity of insoluble matter, we may assume the latter source.

Triphosphate of lime	36
Carbonate of lime	10
Iron and alumina	12
Fluoride of calcium	2
Insoluble matter	28

Probably by this time all the workings in our district, whether in the Lower Greensand or at the base of the Chalk, have been abandoned, the workable parts of both beds having been exhausted.

Building Material.

Stone.

Hard beds of the Lower Chalk have been worked for building and the Totternhoe Stone is quarried at Isleham (see p. 38), the inside of the church at which place is a fine example of chalk masonry. There are also some very beautiful specimens of fine carving in chalk in Ely Cathedral. For internal work chalk is remarkably well fitted, both from its lightness and from the ease with which it can be worked, the former character being of advantage in vaulting and the latter in elaborate carving.

The following quotation, from an old paper, seems to refer to the Totternhoe Stone, just at our southern border, "Some of the beds [of the Lower Chalk] are hard enough to serve the purpose of building stone, and are quarried and shaped in blocks for that purpose. It also endures the fire well, and . . is much esteemed for the back of grates," a use that has probably lapsed. "This stone is dug in the greatest quantities at Reach . . . in the parish of Burwell."*

In its flints the Upper Chalk has furnished the most indestructible of stones. These are used not only in the rough state, but dressed, on one side, to a rectangular flattish face. Mr. Skertchly says that, in the gun-flint district, "the cores from which flakes have been struck are slightly worked up to form building-stones, or *builders*, as they are more commonly called," and they are known under five different names, besides two others for flints that are not cores. The prices of the first five sorts were (in 1879?) 4*s.* a hundred in four cases and 3*s.* in the other case, whilst of the last two sorts, one was sold at from 3*s.* 6*d.* to 5*s.* a ton, whilst the other (stones picked from the surface) could "only bear the expense of cartage."†

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* Prof. Hailstone, *Trans. Geol. Soc.*, vol. iii., p. 248. (1816.)

† On the Manufacture of Gun-flints, &c., pp. 34, 35.

Lime.

The Lower Chalk is or has been worked for lime at Burwell, Isleham and West Row (westward of Mildenhall); the Middle Chalk at Eriswell and Lakenheath; and the Upper Chalk at Wordwell, Elvedon, and Thetford. The sections at Isleham, West Row and Lakenheath are described on pp. 38–40, 44.

Bricks, &c.

The Kimeridge Clay is worked for brickmaking &c. at Haddenham, between Thetford and Ely, and at Chetisham; and the Gault has been worked under the Alluvium of Burwell and Wicken Fens, and at Soham. Most of the brickyards of the district, however, get their supply from the clays and loams of the Drift, as at Mildenhall, Icklingham, Culford, Elvedon, Barnham St. Gregory and Thetford. The former occurrence of other brickyards, in the Drift tract, is shown by such names as Brickkiln Cover or Plantation.

Peat.

The following notes, by Mr. Skertchly, are taken, with a few alterations, from the Memoir on the Fenland, to which the reader is referred for details of the manner of digging the peat and of the tools used.

The word *peat* is unknown among the agricultural population of the Fens. The substance is called *turf*, and where thin, or so weathered as to be unfit for fuel, the term *moor* is used. It is usual to speak of moory land, black land, or fen where the soil is peaty. The word fen has, however, come to be used merely in contradistinction to high land.

The best spots to observe the mode of getting peat are in the neighbourhood of Ely. The largest turbary is in Burwell Fen, but a large one occurs at Coveney.

The peat is dug in parallel trenches about a yard wide and five or six yards apart. The top foot of weathered material is first dug, and comes away in lumps, called *hods*. These are sometimes sold, and they burn well, but from their unwieldy shape are not much in request.

Beneath the "hoddy turf" the material is soft and unweathered, and is dug at once into brick-shaped blocks called *cesses*. The largest I have seen were at Isleham, measuring when dug $20 \times 5 \times 4$ inches. Very small cesses were also dug at the same place, measuring only $12 \times 3 \times 2$ inches. The average size may be taken at about $9\frac{1}{2} \times 6\frac{1}{4} \times 4$ inches, which is the size at Manea. At Coveney they are are somewhat longer, $12 \times 4 \times 3$ being about the size.

A good digger, working from 4 a.m. to 6 p.m., will dig from 8,000 to 10,000 cesses.

When dug the turf is soft and full of water. It is dried in the open air before sale. The usual time occupied in drying is about three months, but in wet seasons, such as 1872, peat scarcely dries at all. It is dug in the spring and summer months,

and allowed to stand in the rows in which it is first placed for about three weeks. The cesses are then turned over, sometimes built into larger rows, and allowed to stand for a month. At the end of this term they are built into large stacks of about 10,000 cesses, and in five weeks or so, according to the weather, are ready for sale and use. The stacks are called *reeks*, and are built by placing four cesses lengthways and four crossways against them, and so on, the courses so alternating that those placed lengthways lie upon those placed crossways. Spaces of about an inch are left between the cesses, in order that a current of air may circulate through the reek. The top of the reek is sometimes covered, but usually left open. When removed to the premises of the consumer the peat is put under shelter, for if at all moist the whole reek will crumble to dust in a provokingly rapid manner when frosty weather sets in. My experience is that it is not cheaper than coal when it can be obtained for 7*s.* per 1,000, even though coals are 35*s.* per ton, but certainly it makes most enjoyable fires when mixed with coal.

Peat is sold by the 1,000 cesses, and the price varies from about 5*s.* to 15*s.* per 1,000, according to quality, locality, &c. In the neighbourhood of Ely the cesses averaged about 10*s.* per 1,000 in 1874, while at Downham they were fetching 15*s.* The term thousand does not necessarily mean 1,000, for the large cesses are counted as two each, so that a thousand large cesses is only 500 in reality. This is a very rough way of calculating, for it is clear that the largest cesses, measuring $20 \times 5 \times 4 = 400$ cubic inches, contain much more than double the material of small cesses, measuring $12 \times 3 \times 2 = 72$ cubic inches, but no more accurate mode of estimating bulk is used. Small cesses cost as a rule about 2*s.* per 1,000 more than large ones, because they are more expensive to dig. They are, however, preferred for domestic purposes, since they are much more convenient. A thousand cesses should weigh about a ton, and, roughly speaking, they are equivalent to about half a ton of coals.

The peat burns with a bright glow, a dull flame, a faint empyreumatic odour, and much more quickly than coal. Very little smoke is produced, but a great deal of rusty-brown ash. Peat is usually burned upon open hearths, but can be used in stoves, provided the pieces are loosely packed. It is the favourite fuel of the Isle of Ely, and in some places, in hiring domestic servants, it is usual to state whether it is used in the kitchen or not, and, as very little soot is produced, they are willing to take service on lower terms where peat is consumed, there being less cleaning required. Moreover it is usual to bank fires at night, by covering a few pieces of burning turf with ashes, when the fire will remain alight many hours. In some cottages the fires are never allowed to go out during the winter months.

Underground Water.

There are probably some wells that get their supply from somewhat sandy or stony beds in the Kimeridge Clay, and the

Coral Rag of Upware must yield water to the very few houses on it; but it is not till we come to the Lower Greensand that there is any notable water-supply, whether from shallow wells, where that formation is at the surface, or from borings to it through overlying beds, as at Soham.

The Chalk, however, is the chief source of water, and the only one yielding a town-supply, both Ely and Thetford depending on this formation and alone having waterworks, the former on Lower Chalk, the latter on Upper Chalk, though reaching perhaps to Middle Chalk. In the many villages wells and cess-pits must often be near neighbours, and it should be remembered that evil communication corrupts good water as well as good manners. The abundance of water in the Chalk is shown by the springs that issue from this rock, such springs being of course merely the overflow of the underground water; and the names of some of the villages are eloquent of springs, to wit, Burwell, Snailwell, Herringswell, Eriswell, and Wordwell.

The low-lying parts of the Drift Gravels must contain much water, as also those higher masses that are underlain by Boulder Clay; but where houses are many this source of supply is open to suspicion.

In August 1890 MR. BENNETT made the following notes of some basins in the Chalk, generally filled with water.

"Stow Water Pit, some two miles N. of West Stow, is of a funnel-shape, perhaps 100 feet in diameter and 20 deep. It is often filled with water to within 3 feet of the top, but never overflows: at the time of my visit the water was very low, and sometimes the pit is dry: the water generally rises about three weeks before Christmas. The basin is natural, though there seems no doubt that it has been artificially enlarged. MR. H. PRIGG kindly took the following measurements on November 12, 1890:—The pit had only 3 feet of water, whilst in the well, at the cottage close by, the depth to water was 21 feet, the well is said to fill rather faster than the pit."

"There is another "pit," not artificialized, about half a mile eastward, at Wordwell Buildings, the water of which runs over. Gravel, not shown on the map, about 3 feet thick, is dug close to this basin, and is evidently a Valley Gravel, brought down by a former stream. MR. PRIGG adds that, at the date above-mentioned, the water-level in a well at the back of the cottages was 12½ feet, and that another well, in the stock-yard, has been known to overflow."

"These basins are interesting as being like those larger Meres on Croxton Heath, near Thetford, and they are the only examples in our district. They clearly result from being below the usual saturation-level of the Chalk, which may rise locally because of some fissure, along which the water may flow more readily."

Details of wells are given in Appendix II.

APPENDIX I. NOTES SUPPLEMENTARY TO THE MEMOIR ON SHEET 51, S.E.

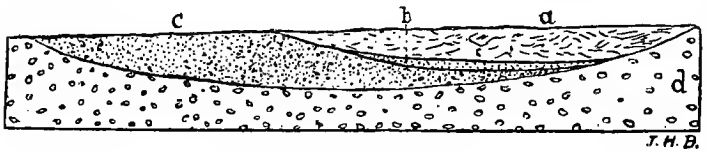
Boulder Clay.

Mr. S. V. Wood, junr., told me, in a letter written in 1875, that he had seen (? some years before), a pit at Coopwell (and about three eighths of a mile N.W. of Stanstead Church), showing a clear section of 12 feet of white finely laminated marl, and he thought this was an included mass in the "Contorted Drift" (Lower Glacial), rather than in the Boulder Clay.

High Level Gravel.

The accompanying illustration of a section near Bury St. Edmunds, by Mr. Blake, was, by some oversight, omitted from the Memoir in which the section is described (p. 13). Being but just outside our district, it may well be given here.

Fig. 31.—*Section in a Pit at St. Edmunds' Hill, eastward of Bury.*



Scale 20 feet to an inch.

a. Buff marly clay, chalky in places.
b. Sand.
c. Gravel, mostly of flint, but with *Belemnites*, limestone-boulders, &c.
d. Bluish-grey Boulder Clay.

River Drift.

In the gravel-pit westward of Ousedeu (described as "below Lidgate," p. 15 of the Memoir on Sheet 51, S.E.) Mr. A. G. Wright has found elephants' teeth and a scraper-like flint implement, and he tells me that the teeth are in the York Museum.

APPENDIX II. WELL SECTIONS.

(Chiefly by W. Whitaker.)

The measurements are in feet.

Cambridgeshire.

Barraway. Haney Hill. Just north of the farmyard, ? E. of the house.

Information from the tenant.

Clay [Gault ?], about 4.
Clay and Sand.
Black Sand, about 6 or 7.

To rock - - 27.

Cottenham. Landbeach Road (southern side), on western side of Watercourse, about 1¾ miles south-eastward from the church.

Trial-boring for the water-supply of the village, 1885.
Communicated by Mr. Peed, of Cambridge.
Shaft about 5 feet.
The yield of water was small, and the quality bad.

	Thickness.	Depth.
Top soil - - - -	3	3
Solid Gault - - - - -	20½	23½
[Lower] Greensand, with hard rock (specimen, calcareous sandstone), about 9 inches thick, 33½ feet down -	18	41½
Blue [Kimeridge] Clay - -	38½	80

The thinness of the Lower Greensand is remarkable, and to it is probably owing the small quantity of water found.

Ely. Legge's Brewery, Market Street.

From information on the spot, 1882.

Can get 3,500 gallons a day.

Sand, &c. [Lower Greensand] -	15
Blue gault [Kimeridge Clay]	5

Isleham. Ely Waterworks.

Communicated by Messrs. Easton and Ffolkes, and by Mr. G. Hook, of Isleham.

24 feet above Ordnance Datum.

Shaft 27½ feet, the rest a bore of 6 inches diameter.
Water-level about 17 feet down. Yield, when pumped down to 22 feet, about 450 gallons a minute.

		Thickness.	Depth.
Soil - - -	about	1	1
[Chalk Marl.]	Chalk - - - -	52½	53½
	Chalk Marl, with very thin coprolite-bed at the bottom - - -	18	71½
Gault.	Clay - - - -	6	77½

SOHAM. Board Schools. From MR. SKERTCHLY'S Notes.

[Chalk Marl.]	Clunch, some very hard -	16¼
	Coprolite-bed, 3 inches -	
Hard blue Gault - - - -		4

Bored deeper, but how deep could not be learnt.

SOHAM. Coprolite Works, near Horsecrofts.

From MR. SKERTCHLY'S Notes. The top 3 beds seen in the pits.

	DEPTH.
Sand, 0 to 2 feet - - - - -	1 ?
[Chalk Marl.] Clunch, 12 feet - - -	13
[Chalk Marl.] Coprolite-bed, 10 inches - -	14 aht.
Gault, 90 feet - - - - - -	104
Red sand and rock [Lower Greensand ?] over 12 feet -	116

MR. G. HOOK has made wells at Soham, about 130 feet deep, into rock [? base of Gault] and then sand, with a good supply of water.

SOHAM FEN. New Schools, Great Drove.

Made and communicated by MR. G. HOOK.
120 feet to rock.
Water overflows, but is brackish.

? SOHAM or STUNTNEY. Near Crooked Drain.

Made and communicated by MR. G. HOOK.
Shaft 30 feet, the rest bored. No water.
[? Kimeridge] Clay, with thick stones, 130.

STRETHAM. For the restoration-works at the church.

From MR. SKERTCHLY'S Notes (1874). Water rose 2 feet only.
Boulder Clay, somewhat sandy, with chalk and flint stones; 2 feet.
Sand [Lower Greensand]: at about 6 feet becomes loamy, by the admixture of dark blue clay: at 15 feet a pebble-bed; quicksand at the bottom.

STUNTNEY. Mr. Ambrose's.

Made and communicated by MR. G. HOOK.
Shaft 40 feet, bored 90 feet.
Fair supply of water, but brackish.

The following Cambridgeshire well-sections, at places in the southern half of Sheet 51, and in Sheet 47, are here given, as supplementary to the Memoirs on 47 and on 51, S.W. and S.E. The Cottenham section has already been described (p. 110), as being in 51, N.W., although out of our district. I have to thank MR. JUKES-BROWNE for some notes on Chalk classification.

CAMBRIDGE. Woolpack Inn.

From MR. CRAWFORD.

	THICKNESS.	DEPTH.
Chalk -	173	173
Gault -	192	365
Greensand -	53	418
Rock ?	3	421
Clay -	1	422
Rock -	1	423
White Marl	5	428
Dark sand -	5	433

This seems to have reached the Kimeridge Clay; but the thickness of Gault and of Chalk seems excessive. The site is probably some way from the town.

LINTON. 1889. 1. Public Well, in the centre of the town; water-level 12 feet down. 2. At Mr. Ficklin's, near the river; water-level 9½ feet down.

Made and communicated by MR. G. INGOLD.

		1.	2.
[Drift.]	Gravel	17	12
	Brown clay	3	—
Chalk		100	110

NEWMARKET. Waterworks, about a mile south of Exning Church.

Communicated by MESSRS. EASTON and FFOLKES.

Shaft 20 feet 4½ inches, with gallery 3½ feet high, at the bottom. Two bore-holes, 12 inches in diameter, of 29 feet 7½ inches, or a total of 50 feet, all in chalk, except for about 1½ feet of soil at top.

NEWMARKET. Moulton Paddocks. 1883.

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

Water-level 40 feet down. Yield, 18 gallons a minute.

	THICKNESS.	DEPTH.
Dug well (old, the rest bored)	—	47
Chalk	15	62
Stone chalk	24	86
Hard grey chalk	10	96
Hard chalk	54	150

NEWMARKET. Sefton Lodge.

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

Water-level 58 feet down, in December 1883.

	THICKNESS.	DEPTH.
Dug well (old, the rest bored)	—	77
Chalk	35	112
Chalk stone and sticky marl	12	124
Chalk	53	177

PAMPISFORD. Near the White Horse Inn. 1885.

Made and communicated by MR. G. INGOLD.

Water rises to within 6 feet of the surface.

		THICKNESS.	DEPTH.
Chalky gravel		7	7
[? Middle Chalk.]	Clunch	8	15
	Yellow chalk	2	17
	Clunch	3	20
[Lower Chalk.]	Soft white chalk, gradually getting tougher	95	115
	Brown sandy chalk [? Totternhoe Stone]	5	120
	Brown chalk, without sand [Chalk Marl]	5	125

SWAFFHAM BULBECK, near the Cambridge Road.

Made and communicated by MR. G. HOOK, of Soham. Bored throughout.

Good supply of water, rising to within 15 feet of the surface.

		THICKNESS.	DEPTH.
Chalk, with a bed of coprolites at the base		93	93
Gault, to rock		93	186
Sand [Lower Greensand]		10	196

WEST WICKHAM. Public Well. 1885.

Made and communicated by MR. G. INGOLD.

All dug. Water 121 feet down.

		THICKNESS.	DEPTH.
[Boulder Clay]	White clay	6	6
	Brown clay	4	10
	Blue clay	38	48
	Clay and chalk	5	53
[Upper Chalk]	Chalk	30	83
	Chalk with occasional layers of clunch	43	126

WEST WRATTING. Public Well, near the church. 1885.

Made and communicated by MR. G. INGOLD.

All dug. Water rises to within 142 feet of the surface.

		THICKNESS.	DEPTH.
[Boulder Clay]	Brown and yellow clay	19	19
	Brown clay and clunch	15	34
[Upper Chalk]	Chalk-rock [? chalk hardened by infiltration]	12	46
	Chalk with a few flints	49	95
	Hard clunch	2	97
	Clunch and chalk	28	125
	Hard clunch	8	133
	Chalk with layers of clunch	16	149

HUNTINGDONSHIRE.

BLUNTISHAM. Northern side. 1874. 32 feet deep.

From MR. SKERTCHLY'S Note-book.

The top part dark bluish Boulder Clay full of striated chalk stones.
Kimeridge Clay beneath [?].
Oxford Clay at the bottom part, *Gryphæa dilatata* being abundant, with an extraordinary number of *Ammonites*, too fragile to be got out. The base, a floor of light-brown water-bearing septaria.

NORFOLK.

THETFORD. Waterworks, on the western side of the high road, about two thirds of a mile N.N.W. of the Railway Station. 1877.

Communicated by MR. J. CHURCH.

Shaft throughout.

Drift. The beds above the Chalk are to be seen in pits close by (*see* pp. 57–59). 50 feet (according to MR. BENNETT).
Chalk. At a depth of 155½ feet a spring of beautiful water was found, yielding a large quantity, over 14,000 gallons an hour having been pumped without reducing the head.

Suffolk.

Note. (Warren.)=Made and communicated by Mr. Warren, of Bury. (F. J. B.)

Ampton. The Hall. (Warren. F. J. B.)

[Glacial Drift]	[Boulder] Clay	40	70
	Sand	30	

Cavenham. The Hall. (Warren. F. J. B.)

Red sand [Valley Drift] -	25	55
Chalk - -	30	

Culford. The Hall.

Made and communicated by Messrs. Legrand and Sutcliff.

Water-level 47 feet down, June 1889.

Clay and stone	2	87
Chalk and flints -	85	

Flempton; in the village. (Warren. F. J. B.)

Black sand, 25

Flempton. Brickyard, a mile S. of the church.

From information on the spot. F. J. B.

[Glacial Drift.]	[Boulder] Clay	8	18
	Loam - -	8	
	Gravel -	2	

To chalk and water.

Hengrave. A mile S. of Flempton Church. (Warren. F. J. B.)

Brickearth -	15	29
Chalk -	14	

Herringswell. In the village. (Warren. F. J. B.)

Black sand -	5	25
Chalk -	20	

Icklingham. Brickyard (Devereux's) marked on the map, more than a mile E.S.E. of All Saints Church. (Warren. F. J. B.)

Brickearth -	30	60
Chalk -	30	

Ingham. Parsonage. (Warren. F. J. B.)

[Boulder] Clay -	50	90
Chalk	40	

LACKFORD. (WARREN. F. J. B.)

	1. Bridge Farm. Black Sand, 15 FEET.	2. The Green.	3. Parsonage.
[Boulder] Clay		5	8
Chalk - -		70	70

LIVERMERE. At the Park. (WARREN. F. J. B.)

[Glacial Drift]	[Boulder] Clay -	15
	Sand -	5

MILDENHALL. Silk Manufactory.

SIR H. BUNBURY. *Trans. Geol. Soc.*, ser. 2, vol. i., p. 379.

? Bored throughout.
Water (found at the bottom) rose, but not to the surface.

		THICKNESS.	DEPTH.
Sandy loam - - - -		1	1
[Middle and Lower Chalk.]	White chalk without flints	35	36
	Yellowish gritty chalk -	5	41
	Grey hard chalk - -	136	177
[? Chalk Marl]	Blue clay - - -	54	231
	Darker, heavier, and harder clay, passing into the next bed - about	10	241
[? Chalk Marl and Upper Greensand]. Blue clay with green sand - -		nearly 10	251
[? Upper Greensand] Greensand with fragments of fossils (particularly *Belemnites* and *Pentacrinites*) - - - -		10 or 11	261½
[Gault] Blue clay with fragments of large shells - - -		9 or 10	271

The classification attempted is doubtful. Can the boring have reached through Gault and Lower Greensand to Kimeridge Clay?

WEST STOW. Heath [? Field]. A mile north of the church. (WARREN. F. J. B.)

Sand, 30 FEET.

The following Suffolk well-sections, at places beyond our present boundary, are given here, as supplementary to the various Memoirs on the districts to which they belong.

BAWDSEY. Bawdsey Manor (on the top of the cliff, a little east of the Ferry). 1890.

Made and communicated by MR. F. BENNETT, of Ipswich.

Water-level 47½ feet down.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Soil		2	3	2	3
[Crag]	White sand	2	3	4	6
	Dark loam sand	11	6	16	0
[London Clay, 87 feet.]	Mottled [discoloured] clay	3	0	19	0
	London clay, with rock [septaria] at 62 to 63½, and at 78 to 78 ft. 10 in.	79	0	98	0
	[Basement-bed.] Mottled loam	1	6	99	6
	[Basement-bed.] Light[-coloured] sandy loam	3	6	103	0
[Reading Beds, 46 feet.]	Mottled clay	1	6	104	6
	Brown sandy loam	2	6	107	0
	Rock	2	0	109	0
	Light[-coloured] sandy loam	5	6	114	6
	Mottled clay	5	6	120	0
	Running sand	11	0	131	0
	Mottled loam	1	0	132	0
	Mottled clay	8	0	140	0
	Mottled loam	4	0	144	0
	Green loam	1	0	145	0
	Mottled clay	2	0	147	0
	Dark green loam	1	0	148	0
	Flint bed	1	0	149	0
Chalk, with flints at 35 levels, from a foot to 14 feet apart		151	0	300	0

BRANTHAM. Xylonite Works. Second well. 1889.

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

Water-level 55 feet down.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Soil		1	0	1	0
[London Clay, 54¾ feet.]	Yellow loamy brickearth	13	0	14	0
	Dark loamy clay	5	6	19	6
	Blue clay, with clay-stone (9 inches) at the bottom	4	10	24	4
	Blue sandy clay	29	8	54	0
	Brown sandy clay	1	9	55	9
[Reading Beds, 49¼ feet.]	Hard mottled clay	3	3	59	0
	Brown sand	3	0	62	0
	Hard mottled clay	4	0	66	0
	Grey ,, ,,	1	6	67	6
	Hard dark clay	2	0	69	6
	Green sand	3	6	73	0
	Mottled clay	1	0	74	0
	Hard blue clay	1	6	75	6
	Sand	7	0	82	6
	Hard blue clay	8	0	90	6
	Silty clay	7	0	97	6
	Green sand	6	6	104	0
	Sand, pebbles and flint	1	0	105	0
Chalk and flints		95	0	200	0

This section differs from that of the former well (published in "The Geology of the Country around Halesworth and Harleston," p. 39) in details, in showing a greater depth, by 43 feet, to the Chalk, and in the water-level being more than 50 feet lower. The site is higher. The water in the former well became too salt for use.

CLARE. Mr. W. H. Smith's. 1883.

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

		Thickness.	Depth.
Dug well [old, the rest bored]		—	145
Rubbish and flints		5	150
Loamy clay		5	155
[Upper Chalk.]	Putty [very soft] chalk	63	218
	Hard chalk and flints	37	255
	Fine sand	2	257
	Chalk and flints	125	382

Probably this well is somewhere near, and not at Clare.

EYE. Brewery. 1887.

Made and communicated by MESSRS. LEGRAND and SUTCLIFF.

Water-level 10 feet down.

		Thickness.	Depth.
[Drift]	Sand, clay, and stones	14	14
	Blue clay	7	21
	Sand and stone	2	23
	White blowing sand	$10\frac{3}{4}$	$33\frac{3}{4}$
	Gravel and sand	1	$34\frac{3}{4}$
	Grey sand and clay	1	$35\frac{3}{4}$
	Grey blowing sand	$6\frac{1}{4}$	42
	Grey blowing sand, and small stones	8	50
[? Crag, or Drift.]	Green sand and clay	$\frac{1}{3}$	$50\frac{1}{3}$
	Grey blowing sand	$12\frac{2}{3}$	63
	Green sand and clay	19	82
	Green blowing sand and shells	6	88
	Flints	1	89
Chalk and flints		111	200

GLEMSFORD. Messrs. Holdsworth and Co. 1888.

Communicated by MR. S. C. HOMERSHAM.

Shaft 30 feet; the rest bored. Supply got. Water-level 72 feet down.

		Thickness.	Depth.
[Glacial Drift.]	Blue clay and stones [Boulder Clay]	$119\frac{3}{4}$	$119\frac{3}{4}$
	Sand	$\frac{1}{4}$	120
Chalk and flints		30	150

IPSWICH. Messrs. Mason's Paper Mills. Between the river and the dock. 1890.

Made and communicated by MR. F. BENNETT.

Shaft 4 feet, the rest bored, and tubed to the depth of 272 feet.

A plentiful amount of water found between 180 and 230 feet down, but the water being salt it was shut out by tubing.

	Thickness.	Depth.
Made soil	4	4
[Alluvium] Black ooze	11	15
[River Gravel] Shingle and sand	14	29
Chalk. The first lot of flints at the depth of 30 feet (with soft chalk below); the next at $233\frac{1}{2}$, and then at 246, 248, 264, and 270, beneath which flints were found continuously	371	400

IPSWICH. Messrs. Tollemache and Cullingham's Brewery. In the central part of the town. 1889.
Made and communicated by MR. F. BENNETT, of Ipswich.
Shaft 7 feet; the rest bored. Tube driven to the depth of 86 feet.
A plentiful supply of good water; rises to within 21 feet of the surface.

		Thickness.	Depth.
Black soil		8	8
Red gravel		14½	22½
[Reading Beds]	Red clay	1½	24
	Blue clay	11	35
Chalk		186	221

IPSWICH. Waterworks. New Well. 1888, 1889. About 32 feet from the older well.

From a drawing, communicated by MR. T. MILLER.

Shaft and cylinders about 46 feet; the rest bored, 15 inches diameter.

		Thickness.	Depth.
Made ground, with gravel at base		19	19
[River Drift.]	Mottled clay — less than	½	20
	Gravel — more than	½	
[? Thanet Beds.]	Bluish clay, and then green clay, passing down into silt	17½	27½
	Black gravel	1	28½
Chalk	Large flints	½	29
	Soft chalk, with a flint-layer, at a depth of over 31 feet. Water in great quantity at 40. Flints at 57 and 58.		
	Very solid chalk marked between 120 and 130 [? extends upward and downward].		
	Flints at 254, and from 266 to 432, in 68 layers (some very small), continuous from 412 to 420.	407	436
	Soft chalk at 278, 314 to 316½.		
	Hard chalk, between close flints, from 326 to 336, at 352 to 356, at 369.		
	Traces of yellow sand at 304. Metallic ore [pyrites] at various places.		
	Crystalline chalk and crystalline fragments at various places, from 352 to 410.		

The limits within which the supply of the old well are believed to be derived are from 58 to 82 feet, and this part in the new well is excluded by tubing. The water seems to come from between 220 and 320 feet, and boring was left off because there was no perceptible increase in the yield below this depth. The supply is practically independent of the old well, for when the head of water is lowered as much as 10 to 12 feet (starting when both wells are at rest) the water falls only from 6 to 9 inches in the old well. With the 12 feet lowering the yield is 950 gallons a minute.

KELSALE. Mr. F. W. L. Lane's. 1889.
Bored and communicated by MESSRS. ISLER.
Water-level 64 feet down. Supply abundant.

		Thickness.	Depth.
[Glacial Drift, ? part Crag.]	Blue (Boulder) clay	15	15
	Sand	55	70
	Blowing sand	36	106
[Crag, 45 feet]	Sand and shells	32½	138½
	Sand and pebbles	2	140½
	Sand and shells	9	149½
	Flints	1½	151
Chalk and flints		70	291

MELTON. Suffolk County Asylum. 1882.
Made and communicated by MESSRS. LEGRAND and SUTCLIFF.
Water-level 97 feet down.

		THICKNESS.	DEPTH.
Dug well (the rest bored)		—	63
[Crag] Sand and shells		11	74
[London Clay, 17 feet.]	Blue clay	14	88
	Dark green sand [Basement-bed]	3	91
[Reading Beds, 35 feet.]	Mottled clay	13	104
	Grey running sand	16½	120½
	Dark sandy clay	3	123½
	Chocolate-coloured clay	2½	126
Chalk and flints		244	370

THORNDON (S. of Eye). The Reformatory.
Made and communicated by MESSRS. ISLER (and from specimens seen by MR. C. REID).
The bore lined some depth into the Chalk.
Water-level 5 feet down. Supply, 16 gallons a minute.

		THICKNESS.	DEPTH.
Dug well		—	14½
[Glacial Drift.]	Stony (Boulder) clay	13	27½
	Loamy (Boulder) clay	10	37½
	Light-coloured sand, with stones	3	40½
	Gravel stones	4	44½
	Sand and stone, with water	26	70½
	Live sand	1	71½
	Sand	2½	74
	Gravel (sandy Jurassic limestone, quartzite, and quartz)	7½	81
	Sand and pebbles (sub-angular flints and quartz pebbles)	5½	87
Chalk and flints		93	180

WITHERSFIELD. Public Well, Burton Green. 1885.
Made and communicated by MR. G. INGOLD.
Shaft 122 feet; the rest bored.
Water-level 118½ feet down.

		THICKNESS.	DEPTH.
[Glacial Drift (Boulder Clay to 100).]	Brown clay	10	10
	Blue clay, with large boulders	33	43
	Light-blue clay, with chalk-stones	31	74
	Dark-blue clay, with stones	4	78
	Light-blue clay, with chalk-stones	22	100
	Brown sandy loam, with chalk	5	105
Chalk		55	160

WITHERSFIELD. Public Well. Near the White Horse. 1885.
Made and communicated by MR. G. INGOLD.
Shaft 95 feet; the rest bored.
Water-level 83 feet down.

		THICKNESS.	DEPTH.
Made earth		3	3
[Boulder Clay.]	Blue clay, with large boulders	6	9
	Blue clay, with chalk-stones	99½	108½
Chalk		51½	160

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Names of Persons are in small capitals (those of the Authors are not entered).
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